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B. T. GALLOWAY, *Chief of Bureau.*

THE VALUE OF FIRST-GENERATION HYBRIDS IN CORN.

BY

G. N. COLLINS,

BOTANIST, CROP ACCLIMATIZATION AND ADAPTATION INVESTIGATIONS.

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Chief of Bureau, Beverly T. Galloway.
Assistant Chief of Bureau, G. Harold Powell.
Editor, J. E. Rockwell.
Chief Clerk, James E. Jones.

Crop Acclimatization and Adaptation Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 5, 1910.

Sir: I have the honor to transmit herewith a paper entitled "The Value of First-Generation Hybrids in Corn," by Mr. G. N. Collins, a Botanist of this Bureau, and recommend its publication as Bulletin No. 191 of the Bureau series.

This report shows how the vigor and fertility of hybrids may be utilized to increase the yield of the corn crop, in addition to other factors of adaptation and breeding.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE VALUE OF FIRST-GENERATION HYBRIDS IN CORN.

INTRODUCTION.

The use of first-generation hybrids offers one of the most promising methods of increasing the yield of corn. The evidence that crossing can in general be relied upon to give an immediate increase of vigor and productiveness appears conclusive, yet the practice seems never to have been applied on a commercial scale. The plan of utilizing first-generation hybrids involves the making of the cross anew each year, and this is readily feasible with corn. Many efforts have been made to develop hybrid varieties, but the increased vigor and productiveness that result from hybridization appear to be confined largely to the first generation and to disappear gradually in later generations.

The present paper reports experiments with a series of first-generation hybrids between widely different types of corn and brings together the results of previous experiments. Investigations that warrant the placing of confidence in this method of increasing the yields of corn are scattered over a long period of years, and most of them appear to have been made in ignorance of similar work previously reported. Individual experiments taken alone have not made it perfectly clear that the results were not accidental, but the assembled evidence forces the conclusion that the increases secured in the first generation by crossing varieties can be made a factor of production comparable in importance to breeding.

It was indicated more than three decades ago that seed produced by crossing two varieties of corn could be relied upon to produce larger crops than the parents, and that this increase was to a great extent lost in following generations.

At about the time when it was discovered that an increase in yield and vigor followed the crossing of two varieties, the attention of investigators was attracted to the possibility of the improvement of corn through what then appeared the more scientific methods of selection. The latter idea was in accord with the most advanced ideas of evolution, while the former appeared as an isolated fact discovered by accident.

It was natural that investigators should follow out what appeared to be the more logical and scientific method. The fact that yields could be materially increased by simply crossing two varieties was lost sight of. Great strides have been made in the knowledge and possibilities of corn improvement by selection, but until the past few years the possibility of utilizing the vigor of first-generation hybrids of corn has remained almost exactly where it was left by the pioneer experimenters.

PECULIAR HABITS OF THE CORN PLANT.

Even after the increased vigor of first-generation hybrids became recognized as a general principle it was not appreciated that the peculiar habits of the corn plant made its commercial application to this crop entirely feasible. Corn is peculiar among the important crop plants in being wind-pollinated and in having the male and female flowers on widely separated parts of the plant. This combination of characters permits the production of crossed seed in large quantities by the simple expedient of planting two varieties together and removing the tassels from the plants of one variety, which will then produce only hybrid seed. The importance of this fundamental difference between the flowering habits of corn and those of other crops has not been sufficiently appreciated. Systems of breeding developed for other plants have been applied to corn, diverting attention from this more simple method of improvement made possible by the peculiar habits of the plant. The use of first-generation hybrids will doubtless be found applicable to other crops, but in few will its utilization be so easily accomplished as with corn.

FIRST-GENERATION HYBRIDS CONFUSED WITH HYBRID VARIETIES.

The utilization of crossing as a means of securing increased yields was further retarded by the failure to realize that the high performance of the generation immediately following a cross is not maintained in subsequent generations. Much effort has been expended in attempting to establish hybrid varieties, overlooking the possibilities of the direct use of hybrid seed of the first generation. The fact that few of the hybrid varieties have been found to have permanent value should not prevent the appreciation of the vigor that immediately follows the crossing.

Until recently hybrids were usually made by hand-pollination and the quantity of first-generation seed was necessarily small. That the plants from this seed were especially vigorous and productive aroused the hope that a happy combination of varieties had been discovered, and attention was at once centered on the increase of the stock and its further improvement. In the succeeding generations diversity appeared and before the desired uniformity could again be secured through selection the increased vigor resulting from the crossing had disappeared.

VIGOR OF HYBRIDS A FACTOR OF PRODUCTION.

Comparatively few recent experiments with a direct bearing on the value of first-generation hybrids have been reported, but all that have been made confirm the earlier results. Taken in connection with the experiments to be reported in the present paper they establish beyond question that the vigor of first-generation corn hybrids is a means of securing increased production that is capable of a very wide application. As soon as the general public becomes acquainted with such a simple and inexpensive means of increasing the yield of this most important crop, a rapid extension of the practice should follow. The great need is for detailed information regarding the particular varietal combinations best adapted to the different local conditions. At present the data are so meager that experiments must proceed empirically, but the lack of detailed information should not obscure the importance of the subject nor stand in the way of utilizing the results already accomplished.

While it would appear safe to recommend this method to all corn producers, the object of the present bulletin is rather to urge the inauguration of experiments in as many parts of the country as possible. It is much as though the possibilities of increased yields through the application of commercial fertilizers were still unappreciated by the general public and experiments to prove their efficacy were being conducted in a few isolated localities. Indeed, the utilization of first-generation hybrids appears to have more general application than the use of commercial fertilizers, but the need for experiments under a wide range of conditions is equally great. As in the use of fertilizers, conditions may perhaps be found where the increase from crossing will be slight or none at all, but even this result should not detract from the fact that under most conditions the increases are significant.

POPULAR BELIEF IN THE SUPERIORITY OF FIRST-GENERATION HYBRIDS.

Though the possibility of utilizing the vigor of first-generation hybrids is only beginning to be appreciated from the scientific standpoint, the increased yields that result from crossing have probably been utilized unconsciously since prehistoric times. It is a regular custom among many native American tribes to carefully plant seeds of different varieties in each hill of corn. This is done for the purpose of increasing the yield. Though the expected increase is usually associated in the minds of the natives with superstitious ideas regarding sexuality in the plants, the vigor secured by such crosses may well have been an important factor in establishing this custom with primitive tribes.

The value of first-generation hybrids is further recognized in a widespread belief among practical seed growers that the plants produced by accidental crosses of pure strains are often exceptionally vigorous. The following statement from Dr. W. W. Tracy, who has had a wide experience in the practical breeding of plants and in commercial seed production, voices this belief:

> The second step is the selection of a few plants which shall come as near to the ideal as possible and the saving of the seed of each of these separately. I recommend this instead of selecting the *best one* because it often happens that the very best plant is in reality a crossed one which owes its superiority to a cross of some exceptionally vigorous but otherwise inferior plant, and this "bar sinister" will be revealed in the inferior quality of plants grown from its seed.[a]

PREVIOUS EXPERIMENTS WITH FIRST-GENERATION HYBRIDS.

EXPERIMENTS IN MICHIGAN.

That the immediate result of crossing two varieties is to increase the yield was shown by definite experiments as early as 1878 by Dr. W. J. Beal, of the Michigan Agricultural Experiment Station. The plan for such experiments had been outlined two years before, in 1876, the same year that Darwin published his classical work on self and cross fertilization in plants, but without knowledge of Darwin's results. Doctor Beal's first statement was as follows:

> To improve or infuse new vigor into varieties (or races I should more properly call them) I propose in case of corn and some other seeds to get seeds from remote parts where it has been grown for some years, and plant near each other and mix them.[b]

Even at this early date Doctor Beal appreciated the fact that the benefits were largely confined to the first generation.

> The good results of such crossing will last for several years, though most apparent the first year.[c]

The nature of the first experiment and its relation to the similar experiments of Darwin are shown in the following quotation:

> From several different sources in remote parts of our State I obtained white dent corn and yellow dent corn for seed. So far as possible I obtained good seed from men who had raised the corn for ten or more years in succession on the same farm.

---

[a] Tracy, W. W. Importance of Uniformity of Varietal Character in Vegetable Seeds. Market Growers' Journal, October 30, 1909, p. 2.

[b] Beal, W. J. Report, Michigan Board of Agriculture, 1876, p. 206.

[c] Loc. cit

I crossed some white dent from one locality with pollen from white dent obtained in a remote locality. This may add vigor to the race, though it will probably not otherwise change the race. The plan was conceived by me about a year ago, and several months afterwards the same kind of experiments were reported on many species of plants by Mr. Charles Darwin, of England. The favorable results of many experiments there given are quite remarkable.[a]

In 1880 the representatives of five different agricultural schools entered into an agreement to test by a uniform experiment at their several stations this method of corn improvement. Each experimenter was to report his experiment to the other parties to the agreement.

The details of this agreement are given as follows:

Each man in his own State shall select two lots of seed corn which are essentially alike in all respects. One should have been grown at least for five years (better ten years or more) in one neighborhood and the other in another neighborhood about 100 miles distant. In alternate rows plant the kernels taken from one or two ears of each lot. Before plowing, thin out all poor or inferior stalks. As soon as the tassels begin to show themselves in all the rows of one lot, pull them out, that all the kernels on the ears of those rows may certainly be crossed by pollen from the other rows. Save seed thus crossed to plant the next year by the side of seeds of each parent. Seeds of one parent can be obtained from the rows not topped. Seeds of the other parent should be planted by themselves to get pure seeds of the same year.

For the second year, select two pieces of ground, each as even as possible, about 4 by 8 rods in extent. Manure it evenly as possible with barnyard manure if any fertilizer is employed. Plow the ground without bed or ridge furrows or, if either occur, plant so that a row of each comes at equal distance from the ridge or bed furrow. Take no unusual pains to make the ground very rich or to cultivate better than usual. Keep the cultivation alike on all parts of the plats as nearly as possible.

On one of these plats plant some of the cross seeds in alternate rows with seeds of one of the parents. On the other plat plant the crossed seeds in alternate rows with the other parent. Seeds of each parent raised the previous year will thus be tested with seeds of the same age from the cross. Take notes of the time in which the plants in each row come up and of the appearance from time to time. Make plats of the corn and be careful to keep everything straight. Take notes of the time of maturing, and when matured cut near the ground the hills of each row and shock separately. After it is cured, husk and weigh the ears and the stalks separately of each row. It would be well to weigh the dried shell corn of each row separately. In the report give the weight of corn and stalks of each row separately, then a summary of the weights of each parent and the crossed stalk. Each experimenter shall report his experiments thus made to each of the other persons entering into this arrangement.

A similar experiment was made at the agricultural college in 1878. In this the advantage shown by crossing of corn over that not crossed was as 151 exceeds 100, and in the case of black wax beans it was as 236 exceeds 100. In a similar experiment made during the past two years at the agricultural college, the corn from seed of crossed stock exceeded that not so crossed as $109\frac{67}{100}$ exceeds 100, or nearly 10 per cent in favor of crossed stock. The experiment was quite carefully made and I do not consider this result as purely accidental.[b]

---

[a] Beal, W. J. Report, Michigan Board of Agriculture, 1877, p. 56.

[b] Ibid., 1880, pp. 287–288.

After a lapse of more than thirty years it is hardly possible to improve or refine the method of experimentation as outlined by this pioneer. His method of comparing yields by alternate-row plantings was also more perfect than that of his successors and is again coming into use as the best that has yet been devised.

In 1881 Doctor Beal made another cross, between two varieties from Oakland and Allegan counties, respectively, and reported the results of the cross as follows:

> The Oakland County seed corn was the better of the two. Owing to an accident we failed to raise any pure Allegan County seed in 1881. The "crossed corn" was only compared with pure Oakland County seed raised last year at the college.
>
> In the spring of 1882, on good soil in a portion of the vegetable garden, three rows of "crossed seed" were planted in rows alternating with three other rows of pure Oakland County seed of 1881. By an oversight each row of each lot was not kept separate. The pure seed yielded 57½ pounds in the ear; the "crossed seed" yielded 69½ pounds in the ear. In other words, the crossed stock exceeded the pure stock as 121 exceeds 100, nearly.[a]

EXPERIMENTS IN INDIANA.

Of the five cooperators entering into the agreement with Doctor Beal to test first-generation hybrids, Prof. C. L. Ingersoll, of Purdue University, seems to have been the only one who reported results. In this case it appears that seed of the variety detasseled was not saved, so that the hybrid was compared with only the male parent. Since in this case the cross was made between two strains of the same variety, this failure does not entirely vitiate the results. The experiment is reported as follows:

> I took corn from Delaware County and also from Switzerland County, in this State, and planted as in first year's directions.
>
> The tassels were removed from the Delaware County corn, so that it was certainly fertilized by pollen from the Switzerland County corn. Both were a white dent variety. The result of corn raised was as follows:
>
> Delaware County (hybrids), 122 pounds, 27.89 bushels per acre.
> Switzerland County, 63 pounds, 14.40 bushels per acre.
> Switzerland County (alone), 72 pounds, 16.46 bushels per acre.
>
> These results, although small, seem to show that in this instance at least, and with the experiment half completed, there is a marked difference in cross-fertilized and self-fertilized corn when the seed from the crossing is obtained from widely separated localities and is of the same variety.[b]

It seems that the experiment was again attempted two years later[c] and hybrid seed was secured, but subsequent reports of the university do not show that the experiment was ever completed, Professor Ingersoll having left the institution.

---

[a] Beal, W. J. Report, Michigan Board of Agriculture, 1881–2, p. 136.

[b] Seventh Annual Report of Purdue University for 1881, p. 87.

[c] Ninth Annual Report of Purdue University for 1883, p. 72.

EXPERIMENTS IN MAINE.

The only reference by subsequent workers to Doctor Beal's experiments so far as we have ascertained is that of Prof. J. W. Sanborn in reporting a similar experiment in Maine.

> Professor Beal found that outcrossed corn, as the average of two years of trial, gave as 131 is to 100 for inbred corn. I found the same result, or as 252 is to 179, and for fodder as 490 is to 350. The facts have a deep significance to our farmers.[a]

EXPERIMENTS IN ILLINOIS.

Nine years after the work of Doctor Beal and apparently in ignorance of his results, Mr. G. W. McCluer reported the results of a series of crosses made at the Illinois Agricultural Experiment Station. He did not give actual yields, but noted the average size of the ear as compared with that of the parents in 18 crosses comprising 14 different combinations of dent, pop, soft, and sweet corn. In 16 of the 18 crosses, or 12 of the 14 different combinations (2 were duplicates and 2 reciprocals), the ears of the first-generation hybrid were larger than an average of the parents, and in 4 of the crosses the hybrid ears were larger than those of either parent. One of the exceptions is stated to have been planted in an unfavorable location. The decrease in the other case was 4.6 per cent. The average increase in weight for the whole series was 14 per cent.

With respect to the uniformity of the first-generation hybrids, McCluer says:

> During the first growing season the uniformity of the crossed plats was very noticeable. Of 142 plats planted with sweet corn, pop corn, and these crosses it is safe to say there was as much uniformity in any one of the crossed plats as in any, and very much more than was found in most, of the plats planted with pure varieties.[b]

The following year, 1891, a number of the ears from this crossbred corn were again planted and Mr. McCluer says:

> Nearly all the corn grown a second year from the crosses is smaller than that grown the first year, though most of it is yet larger than the average size of the parent varieties. The cause of this apparent decrease in size, as compared with the previous year, can only be guessed at. It can not be attributed to the season, because the Queen's Golden–Common Pearl pop corn and Gold Coin–Flour corn crosses grown in 1891 show as large a proportionate increase in size of ear as is shown in any of the crosses grown in 1890. There is probably a strong natural tendency in the crosses to revert to the size as well as the form of the parent types. This is shown in the Leaming sweet-corn crosses, in which the corn reverting to the dent is larger than that reverting to the sweet types. Or the loss of size may be due to a diminution in some way of the vigor imparted by crossing.[c]

---

[a] Sanborn, J. W. Indian Corn. Agriculture of Maine, Thirty-Third Annual Report, Maine Board of Agriculture, 1889-90, p. 78.

[b] McCluer, G. W. Corn Crossing. Bulletin 21, Illinois Agricultural Experiment Station, 1892, p. 85.

[c] Op. cit., p. 96.

In view of the interest that attaches to these early experiments, Mr. McCluer's tabulated results are given as follows:

TABLE I.—*Results of Mr. G. W. McCluer's experiments with corn hybrids at the Illinois Agricultural Experiment Station, showing the effect on the size of ear.*

Cross.	Weight of 10 ears of the male variety.	Weight of 10 ears of the female variety.	Average weight of 10 ears of the two parent varieties.	Weight of 10 ears grown from cross the first year.	Weight of 10 ears the second year after the cross, ounces.	
White dent—Queen's Golden	81	34.5	57.75	76	Ears like the dent type Ears like the pop corn type	64 52.5
Queen's Golden—White dent	34.5	81	57.75	64	Ears like flint corn Ears like pop corn type	55 47.5
Black Mexican—Queen's Golden	36	34.5	35.25	47.5	Types not separated	43.5
Queen's Golden—Common Pearl pop corn.	34.5	27.5	31	42	Not grown a second year.	
Leaming—Mammoth	87.5	61.5	74.5	91	Corn grown from yellow dent kernels Corn from white dent kernels Corn from sweet kernels	86 90 74
Leaming—Mammoth	87.5	61.5	74.5	82	Not grown a second year.	
Leaming—Mammoth	87.5	61.5	74.5	80.5	Not grown a second year.	
Leaming—Triumph	87.5	46.5	67	83	Corn from dent kernels Corn from sweet kernels	86 68
Leaming—Eight-rowed	87.5	41	64.25	72	Corn from white dent kernels Corn from yellow dent kernels Corn from sweet kernels	80 75 58
Gold Coin—Flour corn	63	39	51	78	Has not yet been grown a second year.	
Black Mexican—White dent	36	81	58.5	51	From flint kernels of flinty ears From flint kernels of sweet ears From sweet kernels of flint ears From sweet kernels of sweet ears	53 40 39 38.25
Stowell's—Eight-rowed	57.5	41	49.25	47	From selected ears From self-fertilized ears From cross-fertilized ears	49 38 43
Stowell's—Triumph	57.5	46.5	52	52.5	From self-fertilized seed From cross-fertilized ear Do Seed from selected ears Seed from self-fertilized ears	31 48.5 41 54 39
Stowell's—Mammoth	57.5	61.5	59.5	61	Self-fertilized ear, plat 88 Self-fertilized ear, plat 76 From cross-fertilized ear, plat 86 From cross-fertilized ear, plat 87 Seed from selected ears	43 52 55 45.5 55
Stowell's—Gold Coin	57.5	62.5	60	62.5	From self-fertilized ear, plat 89 From self-fertilized ear, plat 90 From self-fertilized ear, plat 91 Seed from selected ears Seed from self-fertilized ear	48 54 54 58 48
Gold Coin—Triumph	62.5	46.5	54.5	58.5	From cross-fertilized ear, plat 93 From cross-fertilized ear, plat 92 Seed from selected ears	56 50 49
Gold Coin—Eight-rowed	62.5	41	51.75	56	Seed from selected ears	50
Gold Coin—Eight-rowed	62.5	41	51.75	58	Not grown a second year.	

The table further shows the marked decrease in size of ear in the hybrids that follows even one generation of self-fertilization. There is, however, so much "splitting" in the type of the ears in the second year that their size, as compared with those of the second generation, can not fairly be expressed in averages.

The following year, 1892, Morrow and Gardner, also at the Illinois station, reported the results of tests of five first-generation hybrids compared with their parent varieties.[a] In all cases the yield of the cross was greater than an average of the parents and in three cases it exceeded that of either parent. Stated in bushels, the increases above the average of the parents ranged from 1.2 bushels, or 1.9 per cent, to 17.2 bushels, or 28 per cent, the average increase being 13.8 per cent. The average increase of the crosses over the highest yielding parents was 4.66 bushels per acre, or 6.5 + per cent. The comparisons were apparently made in $\frac{1}{40}$-acre plats. The results of the experiment are shown in Table II.

TABLE II.—*Results of experiments by Morrow and Gardner with corn hybrids at the Illinois Agricultural Experiment Station in 1892.*

Variety.	Yield per acre.	
	Number of ears.	Air-dry corn.
		Bushels.
Burr's White	9,960	64.2
Cranberry	9,200	61.6
Average	9,580	62.9
Cross	7,080	64.1
Burr's White	9,960	64.2
Helm's Improved	10,880	79.2
Average	10,420	71.7
Cross	11,000	73.1
Leaming	10,440	73.6
Golden Beauty	8,280	65.1
Average	9,360	69.3
Cross	11,520	86.2
Champion White Pearl	11,080	60.6
Leaming	10,440	73.6
Average	10,760	67.1
Cross	8,760	76.2
Burr's White	9,960	64.2
Edmonds	9,040	58.4
Average	9,500	61.3
Cross	10,400	78.5

It will be noted that the crosses in this experiment were all between good-yielding varieties and apparently under favorable conditions. The relatively uniform results also indicate a small experimental error.

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[a] Morrow, G. E., and Gardner, F. D. Field Experiments with Corn, 1892. Bulletin 25, Illinois Agricultural Experiment Station, 1893, pp. 179-180.

In the bulletin mentioned the practical possibilities of this method of increasing yields were indicated, as follows:

> The fact that increased yields can be obtained by crossing two varieties is pretty certainly established, and a few farmers are changing their practice accordingly. This is quite easily done by planting in one row one variety and in the next another variety, and removing the tassels of the one as soon as they appear. The ears forming on the rows having the tassels removed will be fertilized with pollen from the other rows, thus producing a direct cross between the two varieties. The seed should be selected from the rows having the tassels removed, and the experiments indicate that it will pretty certainly give a larger yield than the average of the parent varieties when planted under like conditions.[a]

The above quotation indicates that the authors considered the principle as established and worthy of practical application. No explanation has been offered why the matter was again allowed to rest at this point, but so far as can be learned no one has since practiced the growing of first-generation hybrids on a commercial scale.

In 1893 four additional crosses were planted, three of the four giving increases over the average of the parents, the average increase being 9.5 bushels, or 7.7 per cent. The results are shown in Table III.[b]

TABLE III.—*Results of experiments by Morrow and Gardner with corn hybrids at the Illinois Agricultural Experiment Station in 1893.*

Variety.	Yield per acre.	
	Number of ears.	Air-dry corn.
		Bushels.
Champion White Pearl	7,680	37.3
Burr's White	10,200	38.6
Average	8,940	38
Champion White Pearl—Burr's White Cross	7,080	28.4
Leaming (average 4 plats)	8,070	34.6
Burr's White	10,200	38.6
Average	9,135	36.6
Leaming—Burr's White Cross	9,480	41.7
Edmonds	7,740	28.3
Murdock (average 4 plats)	9,600	35.7
Average	8,670	32
Edmonds—Murdock Cross	9,840	41.4
Edmonds	7,740	28.3
Burr's White	10,200	38.6
Average	8,970	33.5
Edmonds—Burr's White Cross	9,360	37.8

The fluctuations in the yields of the different varieties and crosses in this experiment are so wide that little confidence can be placed in results. The omission of single members from the series would materially change the average. The lack of uniformity in the conditions is indicated by the great disparity between the yields of duplicate varieties in this experiment, which ranged as high as 15 bushels per acre.[a]

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[a] Morrow, G. E., and Gardner, F. D., loc. cit.

[b] Morrow, G. E., and Gardner, F. D. Experiments with Corn. Bulletin 31, Illinois Agricultural Experiment Station, pp. 359–360.

EXPERIMENTS IN NEW YORK.

After a further lapse of fifteen years, the subject was again approached from a somewhat different direction by Dr. G. H. Shull, of the Carnegie Biological Laboratory at Cold Spring Harbor, N. Y. In his first paper he suggests the possible use of first-generation hybrids in the following statement:

> The problem of getting the seed corn that shall produce the record crop, or which shall have any specific desirable characteristic combined with the greatest vigor, may possibly find a solution, at least in certain cases, similar to that reached by Mr. Q. I. Simpson in the breeding of hogs by the combination of two strains which are only at the highest quality in the first generation, thus making it necessary to go back each year to the original combination, instead of selecting from among the hybrid offspring the stock for continued breeding.[b]

The following year Doctor Shull stated his views in greater detail and reported on the result of crossing two closely related strains.[c] Before these results can be properly appreciated it will be necessary to briefly consider the problem from Shull's standpoint. It is considered that even the most nearly uniform varieties of corn consist of numerous strains, "elementary species" or "biotypes," all more or less mixed and hybridized. To this miscellaneous hybridizing Doctor Shull attributes the vigor and fertility of a variety. The method he suggests for the improvement of corn is to isolate the different strains and by making predetermined combinations to ascertain which will be the most favorable for agricultural purposes. It is fully recognized that isolating the pure strains or biotypes will very greatly reduce their vigor and yield, but by making a combination of the proper strains it is believed that the degree of fertility of the cross will reach that of the most productive plants in the original mixed strain and that an increase of the total yield can be obtained in this way.

Two self-fertilized strains which were separated from a common stock in 1904 and continuously self-fertilized since that time were reciprocally crossed in 1907. In 1908 the yields of these reciprocal crosses were compared with each other, with the self-fertilized parents, and with crossbred stocks of the original variety. Reduced to bushels per acre and placed in tabular form, the yields reported by Shull were as follows:

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[a] Morrow, G. E., and Gardner, F. D., op. cit., p. 338.

[b] Shull, G. H. The Composition of a Field of Corn. Report, American Breeders' Association, vol. 4, 1908, p. 300.

[c] Shull, G. H. A Pure Line Method in Corn Breeding. Report, American Breeders' Association, vol. 5, 1909, p. 51.

Strain A, self-fertilized	23. 5 bushels.
Strain B, self-fertilized	25. 0 bushels (estimated).
A×B	74. 4 bushels.
B×A	78. 6 bushels.
General average of crossbred stock	75. 0 bushels.

From Doctor Shull's standpoint the important point in the above comparison is the increase of 1.5 bushels per acre which the average of the crossed pure strains shows over the average of the cross-pollinated original stock, an increase of 2 per cent.

At the same time a comparison was also made between the yield of self and cross pollinated ears of the same isolated strain. The yield from the cross-pollinated seed was 30 per cent greater than that from the self-pollinated ear. As an instance of the increased vigor of the first-generation hybrid this example is of interest, since it indicates that an increase in yield follows the crossing of even the most closely related plants.

To many producers of corn it will appear hardly practicable to apply this system on a commercial scale. Neither does it appear reasonable on theoretical grounds to look on these anomalous self-fertilized strains as representing the natural condition. It would seem that even the most advantageous combinations might be found without reducing the varieties to the verge of extinction before the cross is made.

But no method of investigation should be rejected for purely theoretical reasons. Until other experimental data are available the effect of previous breeding upon the vigor of the hybrids must remain an open question. The importance of the subject demands that all the phases shall be considered, and those who hold to the conception of "biotypes" and "pure germ cells" will do well to experiment along the lines suggested by Doctor Shull.

EXPERIMENTS IN CONNECTICUT.

A more extensive series of crosses was made by Dr. E. M. East at the Connecticut Agricultural Experiment Station. His results are stated as follows:

> The F_1 generation of 30 maize crosses were grown in 1908 on well fertilized land in Connecticut. They were planted 3 feet 6 inches each way, about four stalks to the hill. Seeds from the same parent ears[a] which were used to make the crosses were also grown for comparison. Only 50 hills of each of the crosses and of each parent could be grown on account of limited space, but the soil conditions were such that a

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[a] "The parent ears were, therefore, one year older, but their germination was good, and their growth equal to inbred seed of the same ages as the hybrid seed."

very fair indication of the comparative vigor of each strain was obtained. Unfortunately crows and chipmunks played havoc with the "stand" in a number of cases, and accurate figures can not be given except in the following four cases where the stand was perfect.

A white dent, No. 8, yielded 121 bushels per acre (at 70 pounds per bushel); a yellow dent, No. 7, which had been inbred artificially for three years, yielded 62 bushels per acre; the cross between the two varieties, No. 7 × No. 8, yielded 142 bushels per acre.

Longfellow, No. 34, an 8-rowed, yellow flint, yielding 72 bushels per acre, was crossed with the same No. 8 white dent, yielding 121 bushels per acre; the resulting cross yielded 124 bushels per acre.

Sturges's hybrid, a 12-rowed, yellow flint with a tall, nonbranching stalk, partaking of the characters of dent varieties, was also crossed with No. 8 white dent. The flint parent yielded 48 bushels per acre, while the cross yielded 130 bushels per acre.

Two families of a yellow dent variety, which had each been inbred artificially for three years, were the parents of the fourth cross. No. 12, yielding 65 bushels per acre, was crossed with No. 7, yielding 62 bushels per acre. The F_1 generation yielded 202 bushels per acre. This last result is somewhat distorted, as five stalks per hill of the cross were allowed to grow, while of the parents only four seeds per hill were planted. About 90 per cent of the seeds produced mature stalks. Notwithstanding the closeness of planting to which this cross was subjected, however, casual observation was sufficient to show that it soared far beyond each parent in vigor of plant and size of ear.[a]

For ease in comparison Doctor East's results are here given in tabular form:

	Yield of female parent.	Yield of male parent.	Average yield of parents.	Yield of hybrid.	Percentage of increase over average of parents.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Per cent.*
White dent × yellow dent	121	62	91.5	142	55
Yellow dent × white dent	72	121	96.5	124	28.5
Yellow flint × white dent	48	121	84.5	130	54
Yellow dent × yellow dent	65	62	63.5	*161	154

*This is the cross of which Doctor East states that five stalks per hill were allowed to grow instead of four, as in the case of the parents. The yield is here reduced by one-fifth from the original figure of 202 bushels to allow for the additional number of hybrid plants that were grown, although by this calculation the hybrid is placed at a disadvantage, due to the closeness of the planting.

It will be noted that the comparison with the parents was in this case very accurate, the plants representing the parents being grown from the identical ears that were used to make the crosses. The yield of one of the parents in the first cross and both the parents in the fourth had, however, been depressed by self-fertilization for three successive years. It is interesting to note in this connection that the introduction into a cross of an inbred strain yielding only one-half that of the other variety here results in increasing the yield above that of the high-yielding parent by over 17 per cent. Furthermore, the highest yield in the experiment was secured from a cross between two inbred strains which without crossing were among those which gave the lowest yields of any represented in the experiment.

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[a] East, E. M. The Distinction between Development and Heredity in Inbreeding. The American Naturalist, vol. 43, no. 507, 1909, pp. 178–179.

Regarding other crosses, Doctor East states:

> In the remainder of the field every possible combination of dent, flint, and sweet maize was grown, and in every case an increase in vigor over the parents was shown by the crosses. It is to be regretted that comparable yields could not be obtained in every instance, but, as a matter of fact, the differences were so apparent to the eye that it is almost unnecessary. The figures presented do not show the average increase to be expected by a cross. The manuring was heavy, the cultivation intensive, and the yields were beyond the ordinary. But they do show that in practically every case a combination of two high-bred varieties of seed corn is more vigorous than either parent.[a]

A NEW SERIES OF HYBRIDS BETWEEN DIVERSE TYPES.

The crosses thus far considered have in all cases been between strains that are comparatively closely related. The most violent crosses are among those reported by McCluer where varieties of sweet and dent, pop and dent, and sweet and pop corns were included. The diversity between these types may seem considerable, representing as they do the extremes of the types now cultivated in the United States, but looked at botanically these varieties appear closely related when compared with the very diverse types that exist in the Tropics.

Over the whole of the United States the interchange of seed has been so extensive and the culture is so nearly continuous that all characters are to a great extent shared by the whole series of varieties, even the most divergent types being distinguished by characters that differ in degree rather than in kind. Even before the advent of the white man the nomadic tendencies of the North American Indians must have operated against any complete isolation of types.

The sedentary habits of the Indians of tropical America are in strong contrast with those of the more northern tribes, and together with the great diversity of natural conditions have operated to produce an enormous number of very distinct types, showing numerous specialized adaptations to different conditions, the agricultural significance of which is only beginning to be appreciated.

As an instance of one of these divergent groups there may be mentioned a type of corn cultivated in parts of the lower plateau of Mexico in a region that receives such scanty rainfall that similar regions in this country would be thought entirely unsuited for corn growing. This corn is so different from the types with which we are familiar that it was given specific rank by Bonafous and named *Zea hirta*.[b] The leaf sheaths are densely covered with long hairs borne on tubercles, the leaves are few and very long and slender, the tassel is frequently unbranched, the spikelets are in groups of four or more instead of two, and the clusters are opposite each other instead of alternate. Even the root system is distinct from that of any of the common varieties of the United States, being spread out near the surface of the ground where the only available water is to be secured in the regions where this type is native. Many varieties inside this type differ among themselves much as the classes of flint, dent, and pop corns differ from each other. In fact, a closely similar series exists in this tropical type, there being varieties which judged by the ears, would be classed as flint and others as pop and dent corns.

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[a] Op. cit., pp. 179–180.

[b] Bonafous, M. Annales des Sciences Naturelles, vol. 17, 1829, p. 156.

While this type is one of the most distinct, many other tropical forms possess characters and habits that are entirely absent or only faintly indicated in United States varieties. Peculiarities of other tropical types will be mentioned in connection with the different crosses that are about to be described.

With a view to securing types adapted to sections of the country where United States varieties are unsuccessful, a considerable series of tropical types and varieties has been brought together. In the season of 1908 about 75 crosses were made among these tropical varieties, and also between them and several United States varieties. A number of these hybrids were grown in the summer of 1909 at Lanham, Md., a few miles from Washington, D. C. The parent varieties of 16 of these crosses were included in the plat and their behavior noted in comparison with the crosses. The experiment was considered as merely preliminary and but 16 hills of each variety were grown. While this number is altogether too small to be conclusive as a comparison of the values of the different crosses, the results as a whole are very significant as an illustration of the general value of first-generation hybrids. It becomes evident that the increase in vigor that earlier experiments have proved to be the rule with crosses of more or less closely related strains has also a very wide application among even the most primitive, unselected, and diverse types of corn. In 14 of the 16 crosses the yield exceeded the average of the parents. In 12 cases it exceeded the yield of either parent, the average increase for the whole series being about 53 per cent.

In the following brief account of the hybrids and their parents, the descriptions will for the most part be confined to the usually recorded characters of height, yield, and character of the ear, which data are sufficient to make the results of this experiment comparable with those previously reported. Detailed observations of the behavior of the parental characters in these and other hybrid combinations have been made, but are not needed for the purpose of this report.

Abnormalities will be briefly noted as a possible indication of the violence of the cross.

HYBRID AH 3, MARYLAND DENT BY HOPI.

Female parent.—An unselected white dent grown in Maryland. The particular plant used as the female parent was grown from the seed of a red ear. This proved to be the most prolific of the uncrossed strains; perhaps on account of its being the only locally grown variety in the experiment. No abnormalities were discovered in any part of the plant or in the ears. Average height, 6 feet 10 inches. The 16 plants grown produced 21 ears and 2 nubbins, weighing 19 pounds.

Male parent.—A variety grown by the Hopi Indians of Arizona. The most striking characteristics of the type are the very large male spikelets and enormous ear stalks. The color of the particular ear used in making the cross was a slaty blue. No abnormalities appeared in the plants grown in this experiment, though in Kansas this strain produced a number of ears with inverted grains, the embryo on the lower side, toward the base of the ear, and also a number of grains with double germs. Average height, 8 feet 10 inches. The 27 plants grown produced 21 ears and 2 nubbins, weighing 20 pounds.

Hybrid.—In spite of the fact that both of the parents yield pollen very abundantly, 6 of the 16 hybrid plants failed to produce pollen. No other abnormalities were observed. The plants were rather diverse, some resembling one parent and some the other. The ears, however, were as uniform as those of either parent and partook of the characters of both. Average height, 7 feet. The 16 plants grown produced 21 ears and 2 nubbins, weighing 20.1 pounds.[a]

HYBRID AH 4, TUSCARORA BY CINQUANTINO.

Female parent.—An 8-rowed soft variety, grown by the Tuscarora Indians of New York. The variety is early and suckers profusely, many of the suckers terminating in ears. Average height, 5 feet 8 inches. The 16 plants grown produced 14 ears and 10 nubbins, weighing 8.5 pounds.

Male parent.—A variety imported from Hungary under the name Pignoletto. A very small seeded, many-rowed type that would be classed as a pop, though unlike any of the American varieties of pop corn. This class of corn is known to the trade as "Cinquantino." The variety is small, without suckers, and very early. No abnormalities. Average height, 4 feet 4 inches. The 14 plants grown produced 14 ears and 1 nubbin, weighing 3.3 pounds.

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[a] The yields of the hybrids and the parent varieties, reduced to pounds per plant, are brought together for comparison in Table IV, p. 29.

Hybrid.—Plants and ears intermediate. No abnormalities. Average height, 6 feet 7 inches. The 15 plants grown produced 21 ears and 14 nubbins, weighing 11.3 pounds.

HYBRID DH 1, KANSAS DENT BY CHINESE.

Female parent.—A white dent developed by Mr. Elam Bartholomew, of Stockton, Kans. The variety has never been closely bred, but has been grown continuously for a number of years and kept up by selection of ears. No abnormalities. Average height, 7 feet 11 inches. The 29 plants grown produced 26 ears and 4 nubbins, weighing 28.6 pounds.

Male parent.—A variety of corn from China, with waxy endosperm, leaf blades borne on one side of the stalk, and silks produced in the angle of the leaf blades.[a]

The parent plant was grown from white seed separated from the imported mixture and had the erect monostichous leaf blades that characterize this variety. The second-year plants from American-grown seed showed these characteristics in a much less marked degree than those grown from imported seed. No abnormalities. Average height, 4 feet 7 inches. The 32 plants grown produced 46 ears and 9 nubbins, weighing 12.4 pounds.

Hybrid.—In the early stages the plants resembled the Chinese parent in having erect monostichous leaf blades, but this character was less marked later in the season. The plants remained dark green during a very dry season. The only indication of abnormality was the frequent production of pistillate flowers on the terminal inflorescences of the suckers. The ears were intermediate in size and appearance and as uniform as those of either parent. Average height, 6 feet 9 inches. The 16 plants grown produced 27 ears and 7 nubbins, weighing 17.5 pounds.

HYBRID DH 2, CHINESE BY CHIHUAHUA.

Female parent.—The same as the male parent of hybrid Dh1.

Male parent.—A starch variety from Chihuahua, Mexico. This variety is peculiar in having the longest leaf sheath at the top of the plant and in having the leaf sheaths covered with fine velvety hairs. No abnormalities. Average height, 8 feet 9 inches. The 14 plants grown produced 13 ears and 2 nubbins, weighing 9.7 pounds.

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[a] This variety is more fully described in Bulletin 161 of the Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, entitled "A New Type of Indian Corn from China."

Hybrid.—The plants of this cross exhibited greater diversity than was shown in any other cross. Two of the plants were so exactly like the female parent, both in plant and ear characters, as to arouse the suspicion that the precautions against foreign pollination had been imperfect and that the particular grains producing these plants were self-pollinated. This appears the more probable from the nature of the Chinese plants, which makes it especially difficult to exclude pollen from the tips of the silks that appear directly in the angles of the leaf blades. While the plants showed the complete range of the parental characters, the ears, with the exception of those noted above, were fairly uniform. One interrupted ear was produced; that is, a portion of the ear near the middle produced only staminate instead of pistillate flowers. Average height, 8 feet 3 inches. The 16 plants grown produced 25 ears and 18 nubbins, weighing 15.25 pounds.

HYBRID DH 3, HOPI BY CHINESE.

Female parent.—A plant from a white seed of the Hopi variety described as the male parent of hybrid Ah3.

Male parent.—White Chinese. The same as the male parent of hybrid Dh1.

Hybrid.—Plants fairly uniform, showing characters of both parents. Ears remarkably uniform, more nearly resembling the female parent. The only abnormal feature was the frequent exsertion of the ear beyond the husks. Average height, 8 feet 4 inches. The 16 plants grown produced 28 ears and 2 nubbins, weighing 20.4 pounds.

HYBRID DH 4, CHINESE BY XUPHA.

Female parent.—Plant from a white seed of Chinese similar to the male parent of hybrid Dh1.

Male parent.—A black, semistarch variety from Salvador. No abnormalities. Average height, 8 feet 8 inches. The 14 plants grown produced 21 ears and 5 nubbins, weighing 8.8 pounds.

Hybrid.—The hybrid ear from which these plants were grown was poorly matured. Plants and ears exhibited a number of abnormalities. Eight suckers and two main stalks bore small ears at the base of the tassel, below which were a number of supernumerary leaves. In two cases the margins of the leaf sheaths were grown together, forming a cylinder. About half of the ears produced staminate flowers; some were interrupted and many had a long staminal portion at the tip. Average height, 7 feet 10 inches. The 16 plants grown produced 18 ears and 18 nubbins, weighing 8.6 pounds.

HYBRID DH 6, BROWNSVILLE BY CHINESE.

Female parent.—A many-eared variety of white dent from Brownsville, Tex. The most striking peculiarity of this variety is the length of the husks, which extend far beyond the tip of the ear and are tightly closed. Although the ear from which these plants were grown was cross-pollinated, 9 seedlings out of 48 were albinos. The yield of this variety would have been slightly higher if the growing season had been longer, lower ears on many of the stalks being immature. The plants were rather weak rooted and fell badly before high winds. Average height, 9 feet 9 inches. The 15 plants grown produced 25 ears and 8 nubbins, weighing 11.6 pounds.

Male parent.—White Chinese similar to the male parent of hybrid Dh1.

Hybrid.—The plants showed few traces of the Chinese characters. The ears were not lacking in uniformity. Husk characters similar to the female parent. The full yielding power of this hybrid was not shown on account of early frosts. No abnormalities. Average height, 9 feet 6 inches. The 16 plants grown produced 35 ears and 17 nubbins, weighing 18.6 pounds.

HYBRID EH 1, HOPI BY ALGERIAN POP.

Female parent.—Same as the male parent of hybrid Ah3.

Male parent.—A type from Algeria with beaked grains that must be classed as pop corn. Its most pronounced peculiarities are the position of the ears, which are only 2 or 3 nodes from the top of the plant, and the nature of the pericarp, which is semiopaque but not colored. No abnormalities. Average height, 5 feet. The 16 plants grown produced 20 ears and 6 nubbins, weighing 5.5 pounds.

Hybrid.—Plants uniform and intermediate. The ears produced were quite unlike either parent, as large or larger than those of the female parent, but with very small grains. The only abnormalities were the production of ears at the base of the tassel on a few of the suckers, two "bears' foot" ears, and one branched ear. Average height, 9 feet 6 inches. The 15 plants grown produced 21 ears and 5 nubbins, weighing 13.6 pounds.

HYBRID GH 2, TOM THUMB BY QUEZALTENANGO BLACK.

Female parent.—A very small variety of pop corn. The plants are from 8 inches to 2 feet in height and bear diminutive ears about 2 or 3 inches long. No abnormalities. The 6 plants grown produced 7 ears, weighing 0.6 pound.

Male parent.—A very tall variety from the high mountains of the western part of Guatemala. The ears are borne very near the top of the plants and are consequently late in maturing. Although apparently an unproductive type the yield here given is little indication of what the variety might do if the season permitted maturing. The cross was made to test the possibility of making crosses between varieties that represented the extremes in size. Average height, 9 feet 6 inches. The 15 plants grown produced 9 nubbins, weighing 1.5 pounds.

Hybrid.—Plants intermediate but exhibiting considerable irregularity in size. Ears averaging 7 inches long, fairly uniform. The principal abnormality was shown in the leaves, which were crumpled and distorted in all the plants. The color was so dark as to be abnormal. While this cross showed distinctly an increase in vigor over that of the parents, the yield of both parents was so small that the amount of the increase should not be considered. Average height, 6 feet 7 inches. The 15 plants grown produced 16 ears and 6 nubbins, weighing 6.25 pounds.[a]

HYBRID KH 31, BROWNSVILLE BY GUATEMALA RED.

Female parent.—The same as the female parent of hybrid Dh6.

Male parent.—A red flinty-seeded variety with 12 to 16 rowed ears, from the lowlands of Guatemala. No abnormalities. Average height, 8 feet 11 inches. The 14 plants grown produced 6 ears and 12 nubbins, weighing 4.31 pounds.

Hybrid.—Ears fairly uniform. Plants and ears without abnormalities. Average height, 10 feet 2 inches. The 32 plants grown produced 29 ears and 10 nubbins, weighing 15.6 pounds.

HYBRID KH 62, GUATEMALA RED BY SALVADOR BLACK.

Female parent.—The same as the male parent of hybrid Kh31.

Male parent.—A black variety from Salvador not unlike the female parent. Two plants of this variety produced branched ears. The ear stalks also curved up instead of down, so that the ears crossed the main stem. The 15 plants grown produced 3 ears and 12 nubbins, weighing 4.1 pounds.

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[a] East states "I have repeatedly tried to cross Giant Missouri Cob Pipe maize (14 feet high) and Tom Thumb pop maize (2 feet high), but have always failed. They both cross readily with varieties intermediate in size, but are sterile between themselves." (See East, E. M., A Mendelian Interpretation of Variation that is Apparently Continuous, The American Naturalist, vol. 44, 1910, p. 82.

It may also be noted that this small variety was successfully crossed with a large Mexican dent whose average height was 11 feet 7 inches. In these experiments the Giant Missouri Cob Pipe corn averaged only 8 feet 4 inches.

Hybrid.—Ears very irregular. One plant produced 2 ears, both of which were interrupted. In many others the ears exceeded the husks. The 16 plants grown produced 8 ears and 8 nubbins, weighing 5.25 pounds.

HYBRID MH 13, QUARENTANO BY BROWNSVILLE.

Female parent.—A drought-resistant variety from Chiapas, Mexico. Many of the plants of this variety have very wide leaf sheaths that are closely wrapped around the weak stalk and are the chief support of the upper part of the plant. Average height, 7 feet 6 inches. The 16 plants grown produced 8 ears and 7 nubbins, weighing 4.3 pounds.

Male parent.—The same as the female parent of Dh6.

Hybrid.—Plants and ears very diverse, without the peculiarities of the female parent. Nine of the plants produced ears exceeding the husks. In three cases the ears were interrupted. The inner husks were crumpled at the base of the ear, a not uncommon condition with thick-husked varieties. Average height, 11 feet 5 inches. This is one of the two cases where the yield of the hybrid was below the average of the parents. With such disparity between the yields of the two parents this may mean that the hybrid more nearly resembled the lower yielding parent. The 16 plants grown produced 11 ears and 7 nubbins, weighing 7.6 pounds.

HYBRID MH 15, HUAMAMANTLA BY HAIRY MEXICAN.

Female parent.—A drought-resistant variety with shoe-peg grains, from Mexico. A variety of the hairy Mexican series, though not a pronounced type. The tassels have a few very long primary branches. The season the cross was made this variety had 50 per cent of the ears interrupted. Plants grown from the same original seed in the season of 1909 had no interrupted ears. Average height, 8 feet. The 13 plants grown produced 4 ears and 7 nubbins, weighing 5.2 pounds.

Male parent.—A pronounced type of the hairy Mexican series, with superficial roots, hairy leaf sheaths, and usually unbranched tassels. The poorly protected ears usually decay in the moist fall weather. Average height, 7 feet 11 inches. The 16 plants grown produced 5 ears and 4 nubbins, weighing 2.8 pounds.

Hybrid. Plants irregular, exhibiting nearly the full range of both parents. The stalks were rather weak; the tassels with from 3 to 7 branches. One ear was produced with a staminate portion at the tip. Average height, 9 feet 1 inch. The 15 plants grown produced 7 ears and 9 nubbins, weighing 4.6 pounds.

HYBRID MH 16, ARRIBEÑO BY HAIRY MEXICAN.

Female parent.—Similar to the female parent of Mh15, but a larger variety. Average height, 9 feet. The 15 plants grown produced 10 ears and 7 nubbins, weighing 5.8 pounds.

Male parent.—Same as the male parent of hybrid Mh15.

Hybrid.—Plants similar to hybrid Mh15, but more robust and uniform. A striking characteristic of this cross was that the leaf blades, though slightly shorter, were much broader than those of either parent. The fifth blade of the hybrid averaged 31.3 by 5.6 inches. The corresponding blade of the female parent averaged 35.4 by 4.1 and the male 31.5 by 4.7 inches. Average height, 9 feet. The 14 plants grown produced 9 ears and 7 nubbins, weighing 6.6 pounds.

HYBRID MH 17, HAIRY MEXICAN BY CHINESE.

Female parent.—The same as the male parent of hybrid Mh15.

Male parent.—The same as the male parent of hybrid Dh1.

Hybrid.—Plants and ears fairly uniform. One difference between the parent strains is that in the female parent when more than one ear is produced at a node the secondary ear is borne directly in the axil of the prophyllum. The male parent resembles the United States varieties in having the first secondary ear borne in the axil of the first husk. Of the hybrid plants that produce secondary ears one-half resembled the male and one-half the female in this respect. The only abnormalities noted were a tendency in a number of plants to have the leaves on the upper part of the plant crowded and one ear with a staminate spike at the tip. Average height, 7 feet 4 inches. The 16 plants grown produced 18 ears and 4 nubbins, weighing 9.8 pounds.

HYBRID MH 25, MEXICAN DENT BY TOM THUMB.

Female parent.—A large Mexican variety with a pronounced tendency to produce large secondary ears. One interrupted ear was produced. Average height, 11 feet 7 inches. The 15 plants grown produced 10 ears and 15 nubbins, weighing 7.8 pounds.

Male parent.—The same as the female parent of hybrid Gh2.

Hybrid.—Plants resembling the female parent in most particulars. About one-half the ears exceeded the husks. Average height, 6 feet 7 inches. The 16 plants grown produced 22 ears and 13 nubbins, weighing 8.6 pounds. Though this cross would seem to have been quite as violent as Gh2, no pronounced abnormalities were found.

YIELDS OF FIRST-GENERATION HYBRIDS.

The following table shows the behavior of the 16 crosses and their parents. The yields are given as yield per plant and were calculated by dividing the total weight of the ears produced in the row by the number of plants. The plants were started four in a hill and thinned to one as soon as established.

TABLE IV.—*Yields per plant of 16 corn hybrids compared with that of their parents.*

Name of hybrid.	Yield of female parent.	Yield of male parent.	Average yield of parents.	Yield of hybrid.	Percentage of increase of hybrid over average of parents.
	Pounds.	*Pound.*	*Pound.*	*Pounds.*	*Per cent.*
Ah3, Maryland dent by Hopi	1.19	0.74	0.965	1.25	29
Ah4, Tuscarora by Cinquantino	.53	.24	.385	.75	95
Dh1, Kansas dent by Chinese	.99	.39	.690	1.09	58
Dh2, Chinese by Chihuahua	.39	.69	.540	.95	76
Dh3, Hopi by Chinese	.74	.39	.565	1.28	126
Dh4, Chinese by Xupha	.39	.63	.510	.54	6
Dh6, Brownsville by Chinese	.77	.39	.580	1.16	100
Eh1, Hopi by Algerian pop	.74	.34	.540	.91	69
Gh2, Tom Thumb by Quezaltenango black	.10	.10	.100	.42	(a)
Kh31, Brownsville by Guatemala red	.77	.31	.540	.49	−9
Kh62, Guatemala red by Salvador black	.31	.27	.290	.33	14
Mh13, Quarentano by Brownsville	.27	.77	.520	.48	−8
Mh15, Huamamantla by Hairy Mexican	.40	.18	.290	.31	7
Mh16, Arribeño by Hairy Mexican	.39	.18	.285	.47	65
Mh17, Hairy Mexican by Chinese	.18	.39	.285	.61	114
Mh25, Mexican dent by Tom Thumb	.52	.10	.310	.54	(a)
Average percentage of increase of hybrids over average of parents					53

[a] Where the yield of either parent fell as low as 0.10 pound per plant the percentage of increase of the hybrid is omitted. In dealing with these small quantities it is believed that percentages would be misleading.

Before leaving the subject of increased yields in first-generation hybrids it may be well to summarize the results of the experiments bearing on this question.

To carefully canvass the literature of agriculture for all references to the yield of first-generation hybrids would be a large undertaking, and it is not pretended that the present summary is complete. It is believed, however, that the experiments cited, which are all that have come to the writer's attention, establish the wide application of the principle and give a fair indication of its importance.

Beal (Michigan, 1878–80) in two crosses very carefully compared with the parent varieties secured an increase in both cases, the average increase being 31 per cent.

Another cross by Beal (1882) compared with the best parent exceeded that parent by 21 per cent.

Ingersoll (Indiana, 1881) in a cross between two strains of the same variety secured an increase over the male parent of 95 per cent.

Sanborn (Maine, 1889) in one cross secured an increase over the average of the parents of 41 per cent.

Morrow and Gardner (Illinois, 1892) secured increases in eight out of nine crosses, the average increase being 11 per cent.

Shull (New York, 1908) by first inbreeding and then crossing got an increase over the original mixed stock of 2 per cent.

East (Connecticut, 1908) secured increases in all of four crosses, the average increase being 73 per cent.

Experiments by the writer with primitive types crossed with one another and with United States varieties, first reported in the present paper, gave increased yields in 14 out of 16 cases, the average increase being 53 per cent.

Though the average of the yields of the parent varieties may be considered as a fair standard for judging the increased yields of the hybrids from the standpoint of heredity, the practical value of hybrids must be determined by comparing their yields with those of the more productive parents. To secure evidence on this point it will be necessary to consider the crosses which have been made between good-yielding varieties grown under favorable conditions, excluding those in which there is great disparity in the yields of the parents.

The following table includes all the crosses here reported in which the parents appear to have been fair-yielding standard varieties giving approximately the same yields.

Table V.—*Increased yield of hybrid corn over the more productive parent.*

	Percentage of increase of hybrid over better parent.
Beal (p. 11). "Varieties essentially alike"	51
Beal (p. 11). "Varieties essentially alike"	10
Beal (p. 12). Hybrid compared only with better parent	21
Ingersoll (p. 12). Strains of the same variety	95
Morrow and Gardner (p. 15). Parents differed by 2.6 bushels per acre	0
Morrow and Gardner (p. 15). Parents differed by 15.0 bushels per acre	—8
Morrow and Gardner (p. 15). Parents differed by 8.5 bushels per acre	17
Morrow and Gardner (p. 15). Parents differed by 13.0 bushels per acre	4
Morrow and Gardner (p. 15). Parents differed by 5.8 bushels per acre	18

It will be seen from Table V that in six of the nine crosses significant increases were obtained over the yield of either parent, and two of the three exceptions should, perhaps, have been excluded, since the differences between the yields of the parents were 15 and 13 bushels, respectively.

The experiments thus far reported are too few to warrant any conclusions regarding the nature of the crosses which may be relied upon to yield the greatest increase. It is naturally to be expected that the percentage of increase will be greatest between low-yielding strains, but the greatest increase in bushels per acre may follow the crossing of the more highly developed strains.

Probably none of the crosses here considered were between carefully bred and locally adjusted strains. What the results of such crosses will be is yet to be determined. Since the most carefully selected strains are more or less inbred, a substantial increase would be expected from crossing two such unrelated inbred strains unless they have already approached the limit of production of the corn plant.

Experiments similar to those conducted by Shull may have a special bearing in this connection. The reduction in vigor which accompanies the inbreeding to which his strains are subjected would have an effect similar to growing the plants under adverse conditions and would tend to eliminate all but the strongest individuals. This would, in fact, constitute an effective form of selection, and with such strains thrown into the vigorous condition of first-generation hybrids a maximum performance might be expected.

While the best results may in general be expected from crossing two varieties both of which are productive, crossing with a low-yielding variety may operate to increase the yield above that of a much higher yielding variety with which it is crossed. The Chinese variety mentioned on page 23 is a small variety producing only 0.39 pound per plant in the experiments reported. Yet in four of the five cases where this variety was crossed with higher yielding varieties the yield of the hybrid exceeded that of the variety with which it was crossed. The average yield of the five varieties with which the Chinese corn was crossed was 0.764 pound per plant, nearly double that of the Chinese, yet the average yield of the five hybrids was 1.004 pounds per plant, an increase over the highest yielding parent of nearly 33 per cent. If the increased vigor of hybrids is in any way associated with the distinctness of the parent types, the remarkable behavior of this series of crosses may perhaps be understood. This Chinese variety is one of the most divergent types and must have been isolated from all ordinary types of corn for a very long time. Evidence was presented in a former publication[a] that the introduction of corn in China was probably pre-Columbian. In these and other crosses where low-yielding varieties producing more than one ear to the plant operated to increase the yield of larger-eared types, the greater yields appeared to have been brought about by an increase in the number of ears with only a slight reduction in their size.

EXTENSION OF CORN CULTURE BY FIRST-GENERATION HYBRIDS.

In addition to increased yield in corn-growing regions the vigor of first-generation hybrids may also allow of an extension of corn growing beyond the present area of production.

Even a slight increase in the drought resistance of corn would make possible the extension of corn culture into large regions where the growing of this crop is now too precarious to justify the effort. The subject is of such importance as to warrant the investigation of every possibility.

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[a] A New Type of Indian Corn from China, Bulletin 161, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 20–24.

That the utilization of first-generation hybrids will be found of special value in the drier parts of the country was clearly indicated by the behavior of the hybrids described in these pages.

The season during which these hybrids were grown was one of exceptional drought, affording an excellent opportunity for observing the drought-resisting ability of the different strains and their hybrids. The rainfall at Washington, D. C., for April, May, and June was slightly below the average, and for July and August it was 4.07 inches, less than one-half the normal.

The series included varieties from localities with such extremes of climate as obtain in the plateau region of Mexico and the moist Tropics of the lowlands of Central America. While the differences between the varieties in their ability to withstand drought were obvious, the most striking differences of this kind were between the hybrids and the pure strains. Almost without regard to the nature of the parents the hybrids remained dark green and vigorous when nearly all of the pure strains were giving evidence of the lack of moisture by their curled leaves and yellow color. This ability to withstand drought may have been a factor in the increased yields which the hybrids produced.

Experiments are being made with a series of hybrids in western Kansas and the dry Southwest with the idea of learning which crosses will prove best suited to these extreme conditions.

Experiments at the Virginia Agricultural Experiment Station indicate that first-generation hybrids may be found to withstand excessive moisture as well as drought. While the crosses were apparently undertaken with the idea of establishing hybrid varieties, the results so far as reported apply only to the first generation.

> The native varieties that were crossed with the western corns have developed three or four good strains, and out of some 350 samples tested here this year none have stood the wet season and made as good yields as the improved strains obtained by crossing pure-bred western corn with our best native varieties.[a]

Associated with the general increase in vigor in first-generation hybrids a certain measure of disease resistance may naturally be expected. Many plant diseases that are unable to attack vigorous plants are able to do serious damage to weaker varieties or to plants that are weakened by adverse conditions. The ability of the hybrids to resist drought might at the same time protect them against disease.

In the case of the corn smut, which was the only disease that affected any of the experiments, this factor of disease resistance does not appear to apply, for the attacks of the smut do not seem to depend upon the vigor of the plants. Nothing approaching immunity to this disease has been observed in any of the varieties or the hybrids.[a]

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[a] Vanatter, Phares O. Annual Report, Virginia Agricultural Experiment Station, 1906, p. 55

FIRST-GENERATION HYBRIDS AND CENTRALIZED SEED PRODUCTION.

It is coming to be generally recognized that in corn culture the use of seed not produced locally is a bad practice, and this is especially true of the most carefully selected varieties. The stimulus to the production of high-grade strains of corn is seriously weakened by the extremely circumscribed area in which such strains can be grown advantageously without further selection. Men of exceptional skill and experience who devote their whole time to the development of improved strains can, without doubt, do more effective work in selection than the farmer who is pressed with other work. But as soon as a carefully selected strain is placed under conditions different from those under which it was developed it behaves in a more or less abnormal manner, and appears at a disadvantage when compared with locally adjusted varieties. This factor of local adjustment is so important that if carefully selected strains are to be directly utilized in commercial production the centralization of seed growing must be discouraged. Farmers must be urged to select their own seed or to secure it from a local breeder.

That first-generation hybrids are relatively free from the new-place effects that so seriously interfere with the spread of varieties has not been demonstrated in corn, but may confidently be expected from the analogy of first-generation hybrids in other crops.[b] This does not mean that a given cross will do equally well in all parts of the country, but that it will make little difference whether the crossing is done in one part of the country or another. When it is once ascertained which combination of varieties is best adapted to a particular locality, pure seed of these varieties may be maintained and the crosses made under the supervision of a trained plant breeder at a central station.

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[a] It was repeatedly observed that plants affected with smut were darker green and more vigorous than neighboring plants not affected. This difference was noticed especially in a strain that had been reduced in vigor by self-fertilization. In this case but one plant in the row was affected with smut, and the stalk of this plant measured 3.82 inches in circumference, while the largest of the healthy plants measured only 3.15 inches. The leaves were also broader and dark green, while all the other plants were yellow and spotted.

Except for the deformed parts where the fungus fruited, the smutted plant appeared more nearly normal than any of the others. The presence of the fungus seems in some way to restore the vigor lost through self-fertilization.

[b] Cook, O. F. Local Adjustment of Cotton Varieties. Bulletin 159, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909.

Careful seedsmen who wish to extend the range of territory to which they can supply seed that will be equal or superior to the best locally selected seed should be willing to give careful consideration to the possibility of establishing regular supplies of first-generation hybrid seed for their customers.

FIRST-GENERATION HYBRIDS IN SWEET CORN.

While the production of sweet corn is influenced by very different considerations from the production of field corn, the evidence at hand indicates that the advantages of first-generation hybrids apply to sweet corn with even greater force than to field corn.

In sweet corn, as with field corn, the yield is an important item, and the experimental data here presented warrant the statement that the yield can be very materially increased by means of first-generation hybrids.

With sweet corn, however, the yield is not the only consideration; quality and uniformity are important factors that must be taken into consideration. As regards quality, the evidence indicates that in most cases it will be intermediate between that of the parents. If parents of good quality are chosen, the quality of the hybrid will be satisfactory. The proof of this rests not alone on the few cases where the quality of the first generation of crosses of sweet-corn varieties has been recorded, but on the general fact that the morphological characters of the first generation of crosses in corn are almost always intermediate between those of the parents. With respect to uniformity it may be said that experiments in crossing sweet varieties have not been recorded in such a way as to give direct evidence. On the other hand, experiments in the crossing of field corns make it certain that in this class, with properly chosen varieties, a perfectly satisfactory degree of uniformity can be secured. The first generation of a cross is usually quite as uniform as the parent strains, a condition naturally to be expected in view of the general tendency for all morphological characters to appear intermediate in the first generation. While the strict uniformity required in score-card ratings may not be assured, it is altogether probable that the uniformity of size, color, shape, and time of maturing required by the market will be fully met if reasonably uniform strains are selected as parents.

The important differences between sweet and field corn in the commercial methods of producing and handling seed are all of a nature to make the application of this principle more effective with sweet corn than with field corn. A much larger percentage of sweet-corn than of field-corn growers buy their seed, a practice that is much to be regretted where pure strains are used, since the lack of local adjustment interferes with the proper performance of superior and carefully selected strains, even when the seed is carried only a short distance. First-generation hybrids are to a great extent independent of this delicate adjustment to local conditions. The utilization of first-generation hybrids would tend to obviate the necessity of urging each farmer to breed his own sweet corn, a practice which must surely follow if the highest performance of pure strains is to be secured.

The possibility of growing combinations of highly bred strains over wide areas would enable the work of the few really skilled breeders of sweet corn to be much more effective. While the general principle is very simple and of wide application, its fullest utilization will require a large amount of experimentation to determine the best combinations for each locality and market. A thorough knowledge of the existing varieties would be of the greatest value to anyone undertaking this work, and, as the cross has to be made anew each year, the inventor of a new and superior combination could much more effectively guard his discovery and secure a more adequate reward for his work than is possible to the breeder of a pure strain.

While further experiments are needed to establish the assumption that crosses of sweet-corn varieties will behave essentially the same as crosses of varieties of field corn, the following possibilities of first-generation hybrids are definitely indicated: (1) Increased yield, (2) uniformity equal to that of the parents, (3) quality intermediate between the parents, (4) increased immunity from disease, (5) extension of the industry into new territory, (6) less localization of highly bred strains, (7) increased utilization of the work of experienced breeders, and (8) stimulus to the work of improvement through the possibility of protecting new productions.

METHODS FOR TESTING CORN HYBRIDS.

It is hoped that the present summary of facts and possibilities regarding first-generation hybrids will assist in stimulating experiments, especially by those who are in a position to keep careful records and report the results.

The experiments are of such a simple nature and results may be expected in such a relatively short time that those interested in increased yields should be concerned to learn the possibilities of this method for their particular localities and varieties and to report the results of their experiments as a contribution to the better understanding of the principles involved. Exceptions are to be expected, though none that may not be ascribed to experimental error have yet been reported.

From the standpoint of the investigation the failures of such experiments are often of even greater interest than the successes, since they may lead to better understandings of the factors involved.

In reporting results it would seem desirable to state the facts bearing upon as many of the following points as possible:

(1) *Names and descriptions of varieties crossed.*—While the names of commercial varieties are almost hopelessly confused, some designations are necessary for purposes of reference, and if these are accompanied by careful descriptions many errors may be avoided, as well as a needless duplication of work.

(2) *History of the varieties.*—This should be traced as far back as possible to throw light on the degree of relationship that exists between the varieties crossed.

(3) *Sources of seed and previous methods of breeding.*—Important differences may be expected even where the same varieties are used, depending on whether the seed has been self-pollinated or cross-pollinated; also whether it was the result of mass selection in the field or crib or was derived from a single ear.

(4) *Size of the hybridizing plat and the plats or rows in which the yields are tested.*—The ratio between the area devoted to each variety in the breeding plat and that in which the yield test of the same variety is made should be recorded, since it is a measure of the opportunity for selection. If the breeding or hybridizing plat is small in proportion to the area to be planted, it will be necessary to save a large part of the seed for planting and the opportunity for selection will be correspondingly small. The failure to take this fact into consideration is one of the reasons why large field plantings of purebred varieties so frequently fail to meet expectations of high yields indicated in the breeding plats, where a more rigid selection was practiced.

(5) *Extent of self-pollination in the parent varieties.*—Many varieties produce pollen so little in advance of the silks that a considerable proportion of the seed is self-pollinated, and this operates to diminish the yield of the resulting plants. In such cases a part of the increase that might be ascribed to the crossing of two varieties would in reality be due to the depressed yields of the parent varieties with which the cross is compared. To determine the increase actually due to the crossing, seed from detasseled plants of the parent varieties should be included in the yield test, together with ordinary wind-pollinated seed of the same varieties.

(6) *The method by which the yields are compared and the precautions against experimental error.*—In this connection it should be borne in mind that large plats do not insure greater accuracy. The larger the plat the greater the difficulty of obtaining equal conditions.

Much greater accuracy can be secured by a comparison of a series of single rows or narrow plats and repeating the series as many times as space or seed will permit.

DIFFERENT METHODS OF PRODUCING HYBRID SEED.

While the process of securing hybrid seed is very simple, it is possible to vary the details of the method to suit different objects and conditions. Those wishing to experiment with a considerable series of hybrids will find it convenient to select what is considered the most promising variety for the male parent and plant this variety in every other row. Any number of other varieties can then be planted in the alternate rows and carefully detasseled. Hybrids will then be secured between the variety selected as a male parent and each of the others, and the seed will be in sufficient quantity to make accurate yield tests the following season.

If it is desired to keep accurate pedigrees of individual plants, resort must be had to hand pollination.

The production of hybrid seed on a commercial scale also permits of considerable variety in the details of the method. Whatever method is followed it would seem desirable that the plat in which the hybrid is made be large enough to afford opportunity for selection. The actual size of the seed plat should be governed by the size of the field planting to be made the following season and the ratio should not be greater than 1 to 100. Thus, if the contemplated field planting is to be 50 acres the hybridizing plat should not be less than half an acre.

Perhaps the most simple method for the farmer is to purchase each year a small quantity of seed of two varieties that are known to be well adapted to the particular section and plant in alternate rows in a hybridizing plat, as recently recommended by Doctor East.[a] The varieties must, of course, be of nearly the same length of season, and in case of any difference in this respect the variety that flowers early should be chosen for detasseling. If the farmer wishes to grow his own parent varieties he can do so by alternating the male and female parents each succeeding year and selecting enough seed from the variety not detasseled to supply the hybridizing plat for two years, the first year as the female parent and the following year as the male. The same result could be approximated by detasseling one of the varieties in one half of the field and the other variety in the other half of the field. By this method seed of both varieties would be secured each year, but considerable indiscriminate crossing would take place.

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[a] The Rural New Yorker, May 1 and 8, 1909.

One difficulty, however, with this reciprocal use of male and female parents would arise unless the varieties agree in length of season. No difficulty would be experienced in securing perfect pollination in a short-season variety used as the female parent, but if such a variety were expected to serve as the male parent the tendency to the early shedding of the pollen might leave little or none available for fertilizing a later variety used as a female parent.

The following directions, which have been sent out to several cooperative experimenters, give a concrete example of one of the ways in which the value of first-generation hybrids may be determined:

> Experiments as outlined below involve the use of two varieties and two separate plats. Varieties may be designated as No. 1 and No. 2, the plats as A and B. The plats should be sufficiently separated to prevent cross-pollination between them.
>
> It should be kept in mind that the increased yield can be expected only for the one year immediately following that in which the cross is made.
>
> Plat A is planted with alternate rows of No. 1 and No. 2. The rows planted with No. 2 are to have all plants detasseled. The crop of No. 1 and No. 2 is to be saved separately.
>
> Plat B is planted entirely with variety No. 2 and has alternate rows detasseled. The crop from the tasseled and detasseled rows is to be saved separately.
>
> At harvesting there will be the following lots of seed:
>
> (1) Plat A. Variety No. 1, field-pollinated.
> (2) Plat A. Hybrid between No. 1 and No. 2.
> (3) Plat B. Variety No. 2, field-pollinated.
> (4) Plat B. Variety No. 2, cross-pollinated.
>
> The yields in the year the cross is made should show the comparative value of the two varieties and the effect, if any, of detasseling on the immediate yield.
>
> A comparison of the yield from these four lots of seed the following year should show the yield of the first-generation hybrid as compared with the pure varieties and to what extent the increase, if any, is due to the elimination of self-pollinated seed.
>
> If plat B can not be provided, seed of variety No. 2 should be held for planting the following year in comparison with variety No. 1 and the hybrid seed.

If it is considered important to have the crop of a uniform color, yellow and white varieties should not be crossed, for the grains will be of different colors in the year following the cross. Crosses between dent and flint or between these and sweet corn would also result in a lack of uniformity with respect to the character of the seed. That such differences should occur while the other characters remain so nearly uniform may appear remarkable, but is explained by another of the peculiar habits of the corn plant. Unlike most other plants the seeds of corn show an immediate effect of pollen (xenia).[a] If a white-seeded variety is crossed by one with yellow or black seeds, the new seeds that are produced show the color of the male parent.

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[a] For a discussion of xenia, see Webber, H. J., Bulletin 22, Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture, 1900.

The embryo that forms as a result of a cross-pollination is, of course, hybrid in nature and may differ from the female parent. Owing to a peculiar double fertilization that obtains in corn the developing endosperm as well as the embryo is contributed to by the pollen and may resemble the male parent. With respect to the characters of the endosperm we are already dealing with the first generation of a hybrid and the general law of uniformity in the first generation seems to hold in most instances. There may be no predicting what the nature of the grain will be, but those plants resulting from the same cross may usually be depended upon to be alike.

The diversity that appears in the seed color of first-generation hybrids is only an apparent exception to the general rule of uniformity in first-generation hybrids. The endosperm in which this diversity appears is in reality the second generation of the hybrid and may consequently show the diversity characteristic of second-generation hybrids.

CONCLUSIONS.

The corn plant is naturally cross-fertilized and requires the stimulus of crossing to produce maximum yields. Methods of close breeding that can be applied to other crops with advantage do violence to the nature of the plant and tend to reduce the vigor of growth and the yield of grain.

As a result of the peculiar habits of reproduction of the corn plant, the raising of hybrid seed does not require any special skill or any large increase of labor. The cost involved is insignificant in comparison with the increased yields that are obtained.

No reason is apparent why the vigor of hybrids may not be regularly utilized to increase the yields of the corn crop. A refusal to take this factor into account would be like rejecting the use of commercial fertilizers or failing to take advantage of the increase that may be obtained by selective breeding.

The planting of first-generation hybrid seed as a method of securing a larger crop is to be considered as entirely distinct from the idea that superior varieties can be bred by hybridizing or crossing. Crosses between distinct varieties or strains at once increase the yield, but to maintain this high performance the cross must be made anew each year.

Experiments to determine the value of first-generation hybrids have been made at various times since 1878, but in an isolated and disconnected manner and usually without any adequate appreciation of the possibilities of this method as a regular element of farm practice.

In the literature which has thus far been examined, 19 crosses have been reported. With a single exception these hybrids gave larger yields than the average of the parents, the amount ranging as high as 95 per cent. The series includes experiments in six different States and embraces a wide range of varieties.

Similar increases are here reported in crosses between the members of a new series of types of corn from China, Africa, and the American Tropics, very different from United States varieties and very unlike among themselves. These experiments show that a very wide application of this principle is possible.

In addition to increased yields there is reason to believe that the increased vigor of first-generation hybrids may become an important factor of adaptation to different conditions of growth. The hybrids appear not to require the delicate adjustment to local conditions necessary to the proper performance of pure strains. The utilization of hybrids may be expected to extend the range of utility of the high-yielding types beyond the present range of adaptation of such varieties.

First-generation hybrids are a distinct factor in the problem of securing varieties of corn with adaptations that fit them for special conditions. The increased vigor which these hybrids possess should make possible their growth in regions where pure strains fail and should also provide some measure of disease resistance.

The advantage of crossing distinct varieties is equally applicable to the improvement of sweet corn and affords a measure of protection to those discovering new and valuable combinations.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 192.

B. T. GALLOWAY, *Chief of Bureau.*

DROUGHT RESISTANCE OF THE OLIVE IN THE SOUTHWESTERN STATES.

BY

SILAS C. MASON,
Arboriculturist, Crop Physiology and
Breeding Investigations.

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Chief of Bureau, Beverly T. Galloway.
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Chief Clerk, James E. Jones.

Crop Physiology and Breeding Investigations.

SCIENTIFIC STAFF.

Walter T. Swingle, *Physiologist in Charge*.

S. C. Mason, *Arboriculturist*.
G. P. Rixford, *Expert*.
E. M. Savage, *Assistant Plant Breeder*.
Bruce Drummond, W. L. Flanery, E. W. Hudson, M. A. Downes, and Henry H. Boyle, *Assistants*.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 30, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 192 of the special series of this Bureau the accompanying manuscript, entitled "Drought Resistance of the Olive in the Southwestern States." This paper was prepared by Prof. Silas C. Mason, Arboriculturist in Crop Physiology and Breeding Investigations, and has been submitted by Mr. Walter T. Swingle, Physiologist in Charge, with a view to its publication.

The data upon which the paper is based were obtained from the study of olive plantations made in Arizona and California, started under irrigation, but afterwards, through the failure of the water supply, left to their fate.

While most fruit trees and vines planted under similar conditions soon perished, the olive trees have survived and made considerable growth, showing themselves to be true desert plants having marked drought-resistant characters.

So strong is this characteristic in the case of some of the varieties of olives grown for oil that it is considered desirable to investigate the possibility of olive culture for oil production in those areas in the Southwest having favorable conditions as to temperature and soil, but with a rainfall not heretofore believed to be sufficient for crop production. At the same time those who desire to experiment should be warned not to plant extensively until the possibilities of fruit production in any particular region have been thoroughly investigated.

With the enactment and enforcement of the Pure Food Law the production of olive oil in the Western States is now on a much different footing from that of a few years ago. Where large quantities of cheap adulterants and substitutes were then sold as pure olive oil, now the olive grower has a market for his product on its merits. With the better prices now prevailing, there seems to be encouragement for a considerable extension of the oil-olive industry.

Mr. Thomas H. Kearney has published a bulletin in this series, entitled "Dry-Land Olive Culture in Northern Africa," describing the methods pursued in dry-land olive culture in southern Tunis, methods which are now being tested in this country by Prof. S. C. Mason and Mr. Kearney in cooperation.

Respectfully,

G. H. POWELL,
Acting Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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DROUGHT RESISTANCE OF THE OLIVE IN THE SOUTHWESTERN STATES.

INTRODUCTION.

Olive culture in the United States has passed through many vicissitudes. Hence, for the fullest knowledge of this industry to-day we should study not only those cases where olive planting has been a financial success, but the frequent instances where a more or less successful growth of olive trees has been obtained without a remunerative production of fruit. The olive tree may maintain life and even make considerable growth under conditions of drought and heat so severe that only the most hardy types of desert trees are able to survive them, yet the margin between such a purely vegetative growth and the production of fruit in remunerative quantities may be a very wide one, so wide that to invest money in the planting and care of olive trees on a commercial scale under such conditions would be sheer folly.

Again, it may occur that one olive grove is producing bountifully while another near by, under substantially the same conditions as to temperature, rainfall, and soil may give but a scant return. Here the choice of varieties, the distance of planting, and the methods of culture and pruning, factors all within the control of the grower, may be quite sufficient to explain the difference between success and failure.

In fact with any given example of olive trees which do not fruit, especially if they are distant from productive trees for comparison, only the closest study and thorough experimentation can determine how narrow the margin may be between their present conditions and those of profitable fruit production.

When any plant of economic value is found to possess great ability to resist drought or heat that fact in itself becomes a matter worth close investigation. How does it obtain its supply of moisture? By means of deeply penetrating roots or of superficial roots exploring great areas? Has it some provision for the storage of moisture in time of surplus? Does it possess peculiarities of stem or leaf structure by which the small moisture supply is conserved to the utmost and the living cells insulated and protected in the most effective manner against the desiccating effects of dry air and intense heat? We may even inquire whether its cycle of growth in relation to the seasons does not undergo an adjustment adapting itself to periods of drought and rainfall.

The present bulletin is an attempt to answer such questions in relation to the olive, and the material upon which it is based has been furnished by a number of plantations of olives made in the more arid parts of Arizona and California, where through failure of the irrigation systems the trees were thrown on their own resources. It is noteworthy that in all such cases where besides olives other fruit trees were planted, few of the olives died and almost without exception all other fruit trees perished.

DRY-LAND OLIVE INVESTIGATIONS.

In the writer's study of the possibilities in dry-land tree growth in southern Arizona and southern California his attention has been called to several cases of abandoned plantations where, along with other fruit and ornamental trees, considerable blocks of olives had been planted. With the failure of the irrigation canals and the consequent cessation of care and culture of the trees, almost all kinds died.

The survival of the olives, and not only their survival but continued growth and luxuriant appearance, was so notable a feature as to attract the attention of observing ranchmen of the vicinity, for it must be kept in mind that these were localities where irrigation was not simply a convenience, but an absolute necessity to the growing of every crop at present known to them.

The examples given below showing not the results of careful test and experimentation but results obtained unwittingly and in the face of disaster seem worthy of careful record when studied in the light of the remarkable dry-land olive culture in Tunis, for the first time brought to the attention of this country by Mr. Thomas H. Kearney,[a] of the Bureau of Plant Industry.

EXAMPLES OF DROUGHT RESISTANCE OF THE OLIVE IN THE UNITED STATES.

AN ABANDONED OLIVE GROVE AT CASA GRANDE, ARIZ.

The first of the abandoned plantations noted was that known as the Bogart-Degolia ranch, 2 miles south of Casa Grande station in Pinal County, Ariz. (See fig. 1.) The altitude of the station is about 1,396 feet, and the olive orchard is only a few feet higher. The mean annual temperature for the twenty-three years recorded is 72° F., and the average annual rainfall is 6.88 inches.

---

[a] See "Dry-land Olive Culture in Northern Africa," Bulletin 125, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908.

TABLE I.—*Average rainfall by months and annual average for Casa Grande, Phoenix, Maricopa, and Mesa, Ariz., for the years from 1897 to 1908, inclusive.*[a]

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Casa Grande	[b]1.04	0.86	[b]0.36	0.25	0.03	[b]0.19	[b]0.97	1.03	[b]0.37	[b]0.13	0.88	0.78	[b]6.88
Phoenix	1.10	.90	.51	.51	.05	.11	1.03	.98	.98	.32	.89	.72	8.11
Maricopa	.78	.72	.38	.33	.04	.16	.91	.83	.52	.25	.72	.78	6.41
Mesa	1.11	1.02	.80	.49	.08	.12	.83	1.31	.59	.35	.861	.01	8.60
Average	1.01	0.87	0.51	0.39	0.05	0.14	0.93	1.04	0.62	0.26	0.84	0.82	7.52

[a] The figures of this table were kindly furnished by Mr. L. N. Jesunofsky, section director, Weather Bureau, Phoenix, Ariz.

[b] These means were obtained by substituting the mean of the month specified in places where the record was wanting.

Figure 2 shows graphically the average rainfall by months for Casa Grande, Ariz., and adjacent stations, from 1897 to 1908, inclusive. The two periods of greater rainfall each year, one culminating in August and one in November, with May and June nearly rainless, are characteristic of the region.

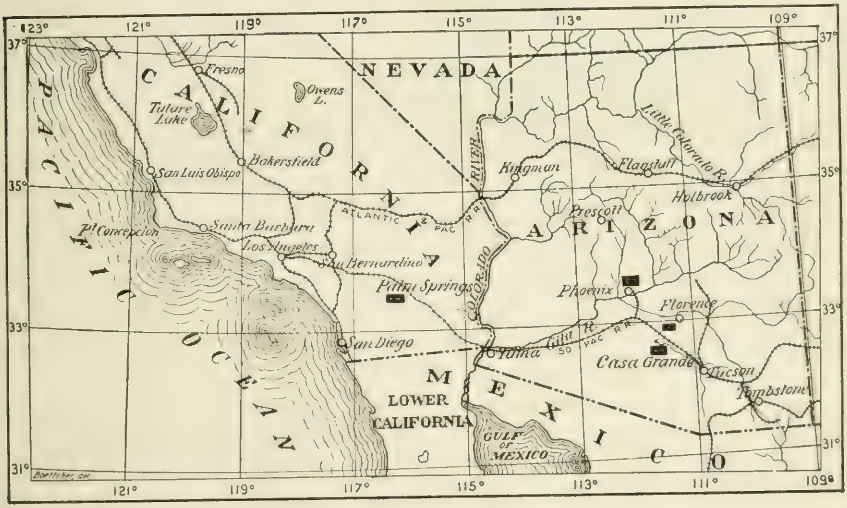
123°
121°
119°
117°
115°
113°
111°
109°
37°
35°
33°
31°
NEVADA
CALIFORNIA
PACIFIC OCEAN
Fresno
Owens L.
Tulare Lake
Bakersfield
San Luis Obispo
Pt. Concepcion
Santa Barbara
Los Angeles
San Bernardino
Palm Springs
San Diego
ATLANTIC & PAC R.R.
RIVER
COLORADO
Kingman
Flagstaff
Little Colorado R.
Holbrook
Prescott
ARIZONA
Phoenix
Florence
Gila R.
SO PAC R.R.
Yuma
Casa Grande
Tucson
Tombstone
MEXICO
LOWER CALIFORNIA
GULF OF MEXICO
Boettcher, del.

FIG. 1.—Map showing the points in Arizona and southern California where dry-land olive growth was studied.

The range of temperature during the year is from a minimum of 25° or 28° F., with occasional years as low as 17°, to a maximum of 117° to 122° F. The mean relative humidity recorded for Phoenix in Table II and graphically illustrated in figure 3 will not be far from correct for the Casa Grande region.

TABLE II.—*Mean monthly and mean annual relative humidity of Phoenix, Ariz., for the years 1905, 1906, and 1907.*

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1905	61	71	67	58	35	25	29	42	41	40	65	59	49
1906	50	60	48	40	31	20	34	47	30	31	45	65	42
1907	66	58	51	30	28	24	36	44	36	55	55	42	44

The country around Casa Grande is a wide plain, through the level of which the mountains appear to be thrust up, so abruptly do the scattering groups and single low peaks break the surface. These mountains are largely composed of a soft, rapidly disintegrating granite, with much feldspar in its composition, and their decay determines the character of the soil, which is coarse and gravelly around the mountain base, sandy with more of clay a little farther away, and of a stiff clay nature mingled with bars of sand and gravel along the drainage courses, scarcely as yet marked as stream channels, which serve to carry away the run-off from the occasional torrential rains so characteristic of the region.

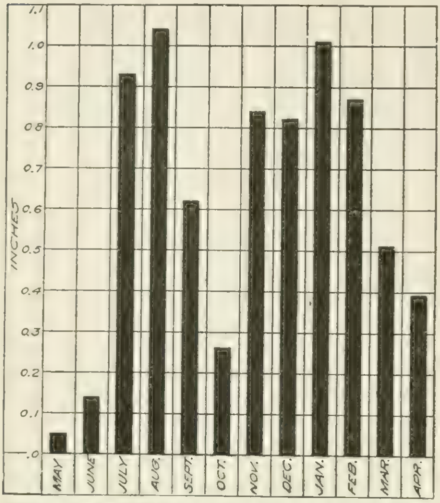

FIG. 2.—Diagram showing the mean monthly rainfall at Casa Grande, Maricopa, Phoenix, and Mesa, Ariz., as presented in Table I.

The most important of these water courses, sometimes dignified on the maps by being called the Santa Cruz River, is locally given the more appropriate name "Santa Cruz Wash." While along its upper course, from the Mexican boundary down to Tucson, there is a pretty well-marked channel and a more or less continuous flow of water, in the neighborhood of Casa Grande a slightly cut channel, a broad, well-marked flood area, and a still broader belt of mesquite growth mark the course of the so-called river.

The popular idea that there is a strong underflow of water the entire length of this valley is given support by the heavy belt of mesquite which occurs with more or less regularity along the course. This tree is well known throughout the desert regions of the Southwest as possessing a remarkable root system, able to penetrate to water-bearing strata at depths of 30 to 50 feet. The further fact that the railroad wells along the line of the Southern Pacific Company, particularly those at Maricopa and Casa Grande, 2 or 3 miles away from the main channel, afford

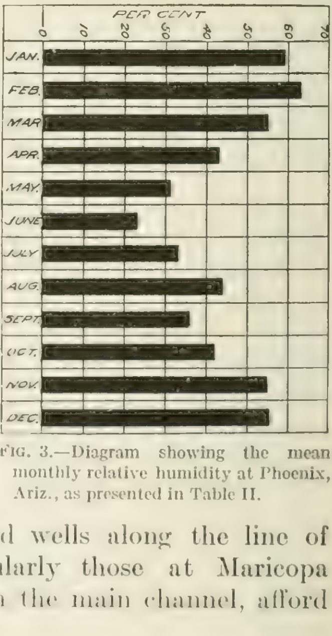

FIG. 3.—Diagram showing the mean monthly relative humidity at Phoenix, Ariz., as presented in Table II.

an abundant flow of water from deep borings, in which the water rises to within 40 to 50 feet of the surface, seems to confirm the impression.

The ranch of which the olive orchard forms a part lies fully 3 miles south of the main Santa Cruz channel, with a gentle slope toward it. A heavy mesquite growth had first to be removed as a preparation for planting, and much growth of the same nature is still to be found adjacent, indicating the presence of a water supply at a depth of 30 to 50 feet. The soil contains a large percentage of coarse granitic sand, but with enough clay to give it considerable body and cause it to bake when dry. (See Tables IV and V.)

THE BOGART-DEGOLIA OLIVE GROVE.

According to the best testimony available, the Bogart-Degolia ranch was planted in 1893. It was at the time of the highest prosperity of the so-called Florence canal, which took water from the Gila River near the town of Florence. About 20 acres of the ranch were set to Muscat and Thompson seedless grapes, figs, apricots, prunes, and olives, there being perhaps 5 acres of olives. The supply of water, while never abundant, was adequate for several years, and the enterprise gave every promise of success.

Owing to the partial failure of the water for the past seven or eight years, the trees have had no water save the rainfall and a little local run-off that the otherwise dry ditches carried to the orchard.

We have no record of the exact order in which the trees began to perish. When examined in March, 1907, all the trees planted were dead except the olives, a few Arizona ash (*Fraxinus velutina*) which had been set along the main ditch where they could profit by the run-off which it could collect, and a few fig trees which still sent feeble sprouts from the base. Appearances would indicate, however, that the apricots and prunes were the first to succumb, followed by the figs.

After the place was deserted, cattle and horses dependent on the scanty desert herbage broke into the inclosure and attacked the olive trees, browsing off all of the tender growth within reach. This fact in itself bears testimony to the scantiness of forage on this plain, for of all the forms of vegetation brought forward as forage plants the olive has not so far been considered in the United States.[a] Many of these trees were browsed and broken till mere prongs and stubs, 3 or 4 feet high, were all that was left of them. None of the trees seem to have been pruned from the first, and the greater number of them had formed several divergent stems from the ground. It was usually where the outer stems had formed a sufficient barrier against the stock that the central ones had attained an adequate growth to enable them to resist attack. Many of these have reached a height of 12 to 15 feet, and a few exceptionally strong specimens are 18 to 20 feet high. (See Pl. I, fig. 1.)

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[a] Mr. Thomas H. Kearney states that during dry years in Algeria branches cut from olive trees are a regular forage supply. See Bulletin 80, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 80.

The foliage is a dark, luxuriant green, and vigorous new growth is being made, even on those trees that have been most severely cropped back by cattle. The whole plantation is a notable landmark on the desert plain and can be seen for a long distance. In fact, uncultivated and abandoned to struggle for itself, the olive has made a winning fight in fair competition with the mesquite of the surrounding desert, even though it has lacked the thorny defense against grazing animals which nature has supplied to the desert tree.

The uniform distance in setting out this entire plantation was in squares 24 feet apart. This would prove to be rather too close planting even in an orchard having an abundant supply of water, but where the supply is as scant as this plain affords experience has shown that this spacing, which provides for 75 trees to the acre, is much too close. The luxuriant growth of a portion of these trees was doubtless made possible by the weakened competition of those closely cropped by stock. The olive tree has the ability to produce a system of shallow roots, fully occupying the ground for a wide radius around each tree. But a few years are needed for a tree to completely take possession of the soil over a radius of 12 feet, after which the struggle must begin with neighboring trees for the available moisture.

A detailed study of the roots of a typical tree was made—a tree with a trunk diameter of only 5 inches, enlarged just below the surface of the ground into a burl 12 inches in diameter and 14 inches in depth, from which radiated 12 roots from a half inch to 2 inches in diameter. Some of these roots had a length of 12 to 14 feet. So numerous were the branches and small feeding rootlets originating from these roots that the soil from a depth of 2 or 3 inches to more than a foot was filled with them.

The description of "Olive root systems" in this bulletin will afford details applicable to all of these plantations.

At the remote areas penetrated by branches from the large roots the ground was contested by feeding roots from the adjacent trees, so that it was hardly possible to turn up a shovelful of earth in the orchard without finding evidence of this reaching out for moisture. Yet there was no taproot and no penetrating to great depths for water, as is so characteristic of the mesquite, which had been the natural occupant of this land. It was a most complete and perfect system for appropriating the moisture in the first 15 or 18 inches of the soil, just that which would be penetrated by the normal rainfall.

The soil, greatly deficient in humus, contains clay enough to make it very hard when dry, and the tramping of grazing stock still further compacted the surface, preventing the ready absorbing of water when a rainfall came. Application of the now well-known principles of thorough cultivation and light furrowing across the slope to secure water storage and the retarding of evaporation by a dust mulch would have aided these trees greatly in utilizing the rain which fell.

DRY-LAND OLIVE GROVE NEAR FLORENCE, ARIZ.

Not far from the Casa Grande and Florence road, in the valley of the Gila River and about 5 miles southwest of Florence (see map, fig. 1), a ranch was developed and a plantation of olives and other fruits was made, probably at about the same time as that at Casa Grande. An area of about 8 acres was set in olives, the trees being arranged in squares 20 feet apart each way. This tract has been kept securely fenced, so that no damage from live stock has occurred. From the scant information that can be gathered these trees have received no irrigation for six years.

The soil is a much stiffer clay than that at Casa Grande. A well near the orchard, now caved in, shows no water for a depth of more than 40 feet. An inspection of this grove shows that while possibly 5 per cent of the original setting of trees failed to grow, but a very few died later. The average height of these trees is about 20 feet. A majority of them grow in the form of stools, sending out several minor stems from near the ground. Some single trunks from 8 to 12 inches in diameter were noted. The formation of a much enlarged burl at the surface of the ground was a very common feature.

A most significant fact was that the trees around the borders of the grove were much larger and of more vigorous and healthy growth than those where there was a perfect stand in the interior. While few of the interior trees are dying, the scantier and less healthy foliage and more slender growth of the branches all testify to the severity of the struggle for moisture which is taking place. (See Pl. II, fig. 2.)

No systematic study of the root development was made, but a number of holes dug in various parts of the grove showed that, as in the Casa Grande grove, the extent of roots was such as to occupy the entire area, fine rootlets being disclosed wherever the soil was turned. Even where missing trees gave a diagonal distance of more than 45 feet between those standing, the roots had extended so as to occupy this space.

A most significant fact concerning this planting is shown in Plate II, from photographs taken in March, 1909. A block of about 3 acres of apricots and almonds planted by the side of the olives is shown in Plate II, figure 1, on the left. The trees had made an excellent growth, but with the failure of the water every one of them has died. On the right are seen the olive trees still making a good growth. A few pomegranate bushes and pepper trees planted in the dooryard adjacent to the olives, while nearly all living, have apparently suffered more seriously from drought than the olives.

DRY-LAND OLIVE TREES NEAR PHOENIX, ARIZ.[a]

A few miles northeast of Phoenix, Ariz., a tract of land was laid off into a sort of residence park under the name of "Las Palmas."[b] Numerous avenues and drives were planted with Canary Island palms, pepper trees, and other ornamentals, and at the same time a considerable number of olive trees was set out, a row along the south side of the southeast quarter being half a mile long. Owing to difficulties about the water supply, cultivation and care ceased over all but a small part of the tract, so that for the past six years no irrigation has been given the olives and peppers on the south side of the section and only a small amount to some of the palms.

The soil here, though gravelly, is much richer in clay and fine silt than that of the Casa Grande tract. This portion of section 22 has for several years been heavily pastured by horses, cattle, and sheep, the trampling of this stock being sufficient to render the ground around the row of olives smooth and compact, so that much of the rainfall would be turned off instead of being caught and allowed to percolate to the roots. A much better supply of forage seems to have prevented the stock in this pasture from browsing the olives as severely as was done at Casa Grande, though apparently sheep have fed off the leaves and small twigs to a height of about 4 feet.

We find this to be a case of growth under decidedly adverse conditions, though not the most extreme. The row of olive trees along the south side of the section is uneven in growth, but many are 12 to 15 feet high, with trunks from 5 to 7 inches in diameter. Here, as in other droughty situations, the olive has a strong tendency to put out sprouts from near the base, thus protecting the trunk from the heat of the sun. This universal habit of olive trees in dry localities, even those that have been headed high enough to expose the trunk, points clearly to the desirability of a method of pruning which will provide a low, spreading head, thoroughly protecting the trunk and main branches.

That several of the trees in this south row should have fruited in 1907 in the face of such privation and neglect, though producing only a light crop, is strong evidence of the hardiness and drought resistance of the olive.

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[a] See map, figure 1. [b] Comprising section 22, in township 2 north, range 3 east.

In the northern portion of the ranch olive trees which had received a little irrigation and less trampling and hardening of the ground produced fair crops of fruit, thus demonstrating that a small difference in conditions may be sufficient to decide between a mere holding on to life and a fair commercial success. The climatic conditions indicated in Table I for Phoenix will be a close approximation to those prevailing at this place. Plate I, figure 2, shows a characteristic tree of the south row in fruit.

THE POPE OLIVE PLANTATION, NEAR PALM SPRINGS, CAL.

DESCRIPTION.

In traveling over the Southern Pacific Railway from Los Angeles to the east, one leaves the orange groves of Colton and Redlands to ascend into a cooler region, an altitude of nearly 3,000 feet being reached in the San Gorgonio Pass. Here, around Beaumont and Banning, are flourishing orchards of prunes, peaches, and apricots, watered from the perpetual snows of the San Bernardino Range, and extensive barley fields moistened by the winter rains. A descent of 2,000 feet in 30 miles to Palm Springs station then brings one seemingly into another country. A sparse growth of desert shrubs and herbs in torrent-washed gravel and among bowlders replaces the orchards and harvest fields, and instead of the refreshing breezes from the snow-capped peaks there is much of the time a sand-laden gale blowing so steadily down the valley that all the desert shrubs lie prostrate and the drift of sand to the leeward of each makes it seem to be marking a nameless grave. Just ahead lies a low range of hills, their original rock formation barely suggested beneath the mantle of sand that centuries of winds have heaped upon them. No landscape could be in more striking contrast with that left behind at Colton and Beaumont.

Taking the trail to the southward from Palm Springs station for a few miles carries one out of the sweep of the winds to a sheltered section containing the picturesque little village of Palm Springs at the site of the old Agua Caliente. (See map, fig. 1.) The Mission Indian village lies on the east side of "Indian avenue" and a little group of homes of the white settlers on the west, all nestling under the shelter of the towering San Jacinto Mountain, whose two peaks, San Jacinto and Cornell, are among the highest in southern California. From a jagged rent in the eastern base of the mountain issues an ice-cold stream of water, a brawling torrent when the mountain showers are heavy or the snows are melting rapidly, but sinking to a tiny rivulet at the end of the long desert summer, barely sustaining life in the little oasis dependent upon it. In fact, during a series of extremely dry years it has happened that the flow of 9 or 10 miner's inches, or about 120 gallons, per minute from the hot spring pool has been all there was to sustain plant or animal life for months at a time.

A little way out on the desert one notices rows of pepper trees (*Schinus molle*), their rich, dark green in sharp contrast with the desert herbs and shrubs, while a nearer approach shows, perhaps, a half-dismantled house and a broken fence inclosing a small field. Gaunt rows of cottonwood trees, a few still keeping up the struggle, the greater part standing stiff and white, seem ghostlike sentinels keeping watch along the line of a ditch that has long since ceased to convey the life-giving water. Acres of grapevine stumps, blocks of dead apricot trees, skeleton branches of bleaching fig trees, a few green sprouts struggling from their bases—all give eloquent testimony to the energy and capital invested in the Palmdale settlement in 1889, when the granite-lined canal brought a supply of water from the Whitewater River across 7 miles of blowing sand to irrigate this sheltered spot at the foot of the San Jacinto Range.[a]

In striking contrast to the impression of desolation offered by the majority of these abandoned fields is that of a tract lying a mile northeast of Palm Springs, Cal.,[b] where, if one ascends to a little elevation above the plain, the check rows in dark, rich green of an olive plantation of 26 acres shows in striking contrast to the brownish green of the creosote bush (*Covillea tridenta*), which forms the natural growth. Here in 1891 was set an olive grove of approximately 3,000 trees, together with some 6 or 7 acres of figs. (See Pl. III, fig. 1.)

CLIMATE OF PALM SPRINGS.

Palm Springs has the typical desert climate, modified somewhat by its proximity to the San Jacinto Range, which cuts off the fierce sweep of the winds which come down through the San Gorgonio Pass and spread out over the country above the Salton Sea. The summer's heat is intense and prolonged, maximum temperatures of 100° F. and over being reached every month from May to September, inclusive, and occasionally even in April and October. The absolute yearly maximum for the ten years from 1897 to 1906, inclusive, ranges from 113° to 122° F., only 1904 failing to reach 116° F. The lowest recorded winter temperature is 28°, but more often 32° F. is the record, and sometimes winters pass with scarcely a trace of frost. Although within 12 miles of the snow-capped San Jacinto peaks, the mean annual precipitation is a scant 3½ inches, with a total of only 0.70 inch for 1903 and a maximum of 9.36 inches for 1905. (See Table III.)

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[a] Since the studies herein described were made, much of the canal stock and a considerable acreage of land have been acquired by persons who have repaired the canal and begun again the appropriation of water from the Whitewater River.

[b] A portion of section 11, in township 4 south, range 4 east.

Scant as this rainfall is it nearly all occurs in the six months from October to March, inclusive. During the six summer months when a temperature of 100° F. is reached almost daily there is scarcely a trace of rain. (See fig. 4.) That any vegetation should be able to pass through this terrible period of heat and drought seems beyond belief to one accustomed to the behavior of plant growths of the regions having abundant rainfall; yet many species of shrubs and three species of trees are native in these hot sands.

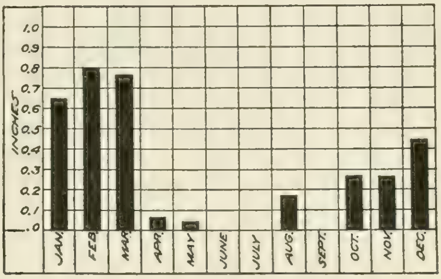

FIG. 4.—Diagram showing the mean monthly rainfall at Palm Springs station, Cal., as presented in Table III.

That the olive, whose beautiful groves are typical of the most favored portions of France and Italy, should be able to survive and even successfully compete with these desert shrubs in their own habitat, when planted among them and then abandoned, gives us a new insight into the real character of this tree that makes it worthy of careful study.

TABLE III.—*Maximum and minimum temperatures and precipitation at Palm Springs station, four miles north of the Pope olive plantation, California, elevation 584 feet, for the years 1897 to 1907, inclusive.*

MAXIMUM TEMPERATURE (DEGREES FAHRENHEIT).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	68	74	83	103	108	111	120	118	104	97	89	78	120
1898	73	88	95	108	102	110	116	115	112	102	92	78	116
1899	82	84	84	102	92	116	116	114	113	96	90	86	116
1900	81	86	97	94	106	111	118	110	107	104	90	78	118
1901	78	98	96	95	98	118	111	114	106	98	90	82	118
1902	98	105	105	98	101	121	116	106	112	95	85	75	121
1903	70	72	85	97	111	112	117	116	112	98	88	81	117
1904	78	86	92	106	103	112	113	111	107	102	96	81	113
1905	72	70	81	78	110	110	122	115	110	98	82	74	122
1906	70	......	88	101	102	112	116	116	106	104	94	75	116
1907	74	84	91	100	95	115	118	......	102	100	88	78	....

MINIMUM TEMPERATURE (DEGREES FAHRENHEIT).

1897	38	32	37	40	39	65	77	81	68	55	42	30	30
1898	36	48	42	54	58	70	78	78	64	62	42	32	32
1899	30	28	46	56	60	66	85	70	70	50	50	32	28
1900	34	38	50	42	52	66	69	70	64	51	48	44	34
1901	30	44	50	58	64	61	75	80	65	65	47	30	30
1902	32	30	42	50	62	59	66	68	60	60	35	40	30
1903	40	32	46	50	54	60	65	68	58	58	50	34	32
1904	32	39	49	53	53	69	75	79	61	62	56	48	32
1905	45	28	50	46	50	60	75	80	70	60	40	30	28
1906	33	......	42	50	58	62	84	70	62	47	32	40	....
1907	30	46	42	55	52	70	72	......	60	60	46	35	30

TABLE III.—*Maximum and minimum temperatures and precipitation at Palm Springs station*—Continued.

PRECIPITATION (INCHES).

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	0	0	0	0	0	0	0	0	0	0	0	1.09	1.09
1898	......	0	0.60	0	T.	0	0	0	0	0	0	.70	....
1899	1.21	0.12	0	0	0	0	0	0.62	T.	0	0.50	2.86	5.31
1900	.80	0	0	0	0	0	T.	0	0	1.29	T.	0	2 09
1901	T.	3.50	0	0	0	0	0	0	0	0	0	0	3.50
1902	.50	0	.50	0.50	0	0	0	0	0	0	.70	.70	2.90
1903	0	0	.70	0	0	0	0	0	0	0	0	0	.70
1904	T.	T.	......	0	0	0	0	1.00	0	.10	T.	0	....
1905	2.16	3.95	1.66	T.	0.48	0	0	0	0	0	1.11	0	9.36
1906	.46	......	3.05	.20	0	0	0	.10	0.05	0	.70	.56	....
1907	1.27	.47	1.27	.15	0	0	0	......	0	1.64	0	T.	....

T.=trace.

SOIL AT PALM SPRINGS.

The soil of the olive orchard is typical of this district. The rock formation is coarse sandstone and granite. The southern face of the mountains is broken by canyons of various widths and depths, originating as rents and fissures in the uplifted rock, but enlarged by the erosion of the mountain torrents, which were apparently during glacial times of vastly greater volume than at present. The result has been an enormous talus of water-worn bowlders from each of the main canyons extending out into the basin to an unknown distance and depth and spreading laterally along the mountain base. Over this is a varying depth of coarse sandy and gravelly soil, in places mixed with a considerable quantity of finer material from the sorting action of wind and water. Several square miles in the Palm Springs and Palmdale region have thus a fair quality of sandy soil, which is lacking in sufficient clay or fine binding material and because of the scanty rainfall and sparse vegetation is low in organic matter. Judging from the quantity of feldspar in the original granitic rock, there is doubtless a good deal of available potash in this soil.

On the particular 40 acres in the olive orchard there is rather less of the finer material in the soil than in that of the Indian reservation lands adjoining on the south. Layers of coarse gravel and cobblestones are often encountered at depths of 3 to 4 feet. The longest winter rains sink so quickly into the soil that there is no trace of stickiness or mud on the following day.

TABLE IV.—*Mechanical analyses of soils from olive orchards at Casa Grande, Ariz., and Palm Springs, Cal., made by the Bureau of Soils, U. S. Department of Agriculture, from samples collected by Mr. S. C. Mason.*

Locality.	Depth taken.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
	Inches.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Casa Grande, Ariz	0 to 6	4.0	15.1	10.4	25.0	11.1	27.1	8.0
Do	6 to 12	3.7	13.5	9.1	26.0	10.0	32.3	5.0
Do	12 to 18	4.4	14.0	9.4	25.0	9.1	32.1	6.6
Palm Springs, Cal	0 to 6	4.0	15.2	42.0	17.7	13.2	7.2	.8
Do	6 to 12	4.0	15.0	15.4	43.4	13.1	8.0	.9
Do	12 to 18	3.4	14.1	14.0	40.2	14.9	11.3	1.6

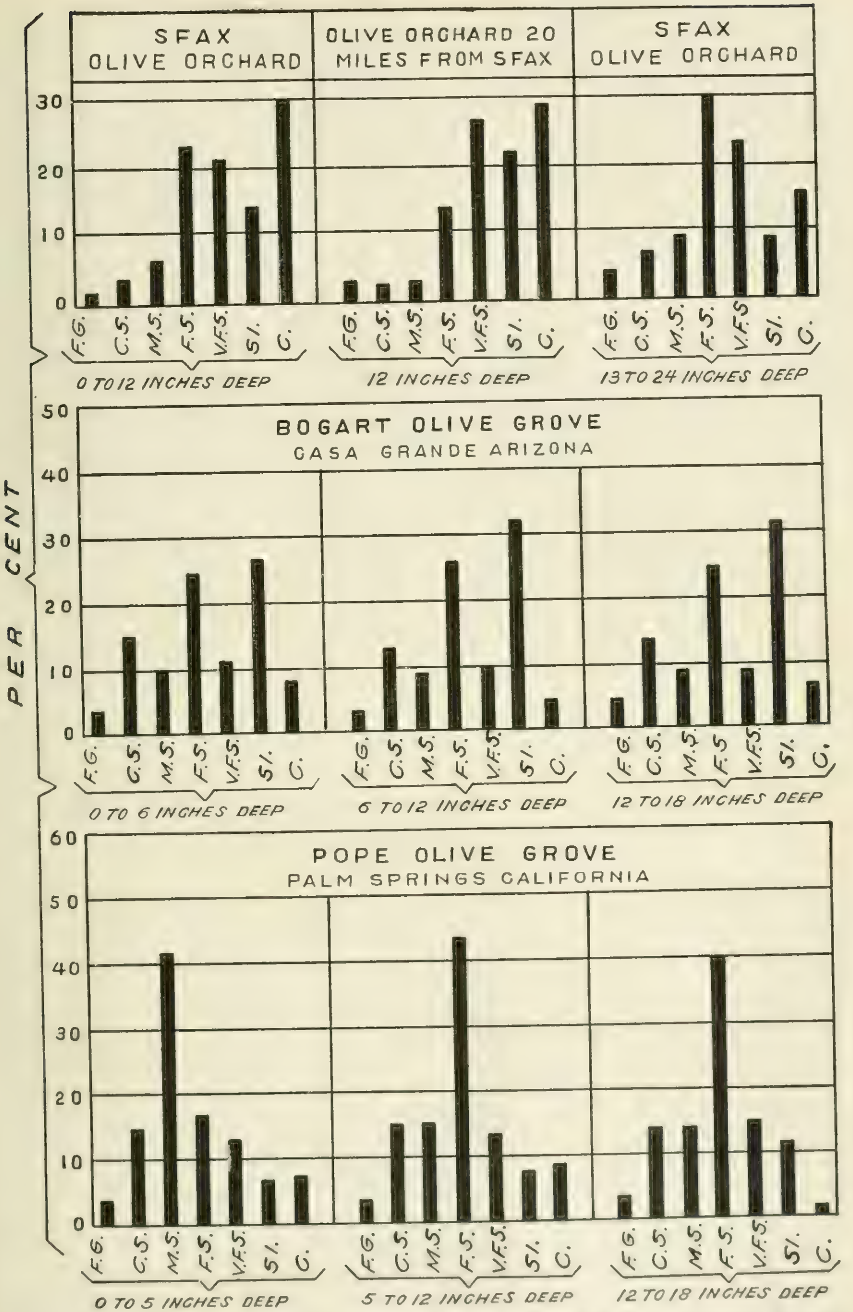

FIG. 5.—Diagram showing the relative percentages of fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt, and clay in dry-land olive plantations in northern Africa (Sfax) and in Arizona and southern California.

TABLE V.—*Analyses for potash, phosphoric acid, calcium, and organic matter in soils from olive orchards at Casa Grande, Ariz., and Palm Springs, Cal., made by the Bureau of Soils, U. S. Department of Agriculture, from samples collected by Mr. S. C. Mason.*

Locality.	Depth taken.	CaO.	K_2O.	P_2O_5.	Organic matter.
	Inches.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Casa Grande, Ariz	0 to 6	1.18	0.98	0.03	0.15
Do	6 to 12	.53	1.00	.22	.46
Do	12 to 18	1.85	1.00	.32	.66
Palm Springs, Cal	0 to 6	1.58	.81	.52	.19
Do	6 to 12	1.58	1.02	.38	.12
Do	12 to 18	1.75	.80	.41	.17

Figure 5 shows in a graphic manner the results of a mechanical analysis of this soil by the Bureau of Soils, as presented in Table IV. This is placed for comparison below a diagram showing the results of a similar analysis of the soil from the Casa Grande olive grove and one from the olive orchards of Sfax.[a] The small quantity of clay and silt and the large proportion of medium and fine sand distinguish

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[a] See "Dry-land Olive Culture in Northern Africa," by Thomas H. Kearney, Bulletin 125, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908, pp. 18–19, as follows:

Mechanical analyses of soil samples from the olive orchards of Sfax.

Locality.	Depth taken.	Fine gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0 mm.
	Inches.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Olive orchard, Sfax	0 to 12	0.2	4.3	7.1	24.1	20.9	14.1	30.0
Do	13 to 24	.4	7.7	9.7	33.9	24.0	9.1	16.0
Do	25 to 36	.5	7.9	10.3	34.3	24.6	7.1	15.7
Do	0 to 12	.2	4.6	6.8	26.4	22.5	13.4	26.2
Olive orchard, 20 miles north of Sfax	(a)	.3	2.7	3.3	14.9	27.0	22.9	29.3

[a] Adhering to olive truncheons, probably about 12 inches.

Chemical analyses of a large number of samples of the Sfax olive soils by the chemist of the Tunisian government show them to be very rich in lime (calcium carbonate), of which there is an average of from 5 to 10 per cent. The potash content is also good, the average being 0.1 to 0.2 per cent. On the other hand, they are rather poor in nitrogen (0.03 to 0.05 per cent) and in phosphoric acid (0.04 to 0.05 per cent). According to Trabut, a high lime content is a very favorable factor in growing olives for oil production, as olives produced in limestone regions are richer in oil and the oil is of better quality then where the soils are deficient in this component. It should be noted that while the nitrogen and phosphoric acid content of the Sfax soils would be considered low for most crops, the high yields and good quality of the oil produced at Sfax are sufficient evidence that the supply of these two elements of plant food must be amply sufficient for the requirements of the olive. This can perhaps be explained by the fact that the roots of this tree occupy so great an area of soil (one-seventh to one-tenth acre) that, while the percentage of these elements to weight of soil is everywhere low, the total amount available to the roots is actually rather high.

this Palm Springs soil in a very marked way from that of the Casa Grande. Both are in striking contrast with samples from the dry-land olive district of Sfax, in northern Africa, described in Mr. Kearney's bulletin previously referred to. The much higher percentage of clay in the Sfax samples gives a very distinct character to that soil, which as it exists in nature impresses one as sandy, owing doubtless to the clay and silt particles being cemented together.

In chemical composition these soils (Table V[a]) show a striking similarity in the lime content, having only one-eighth to one-fourth as much of that element as is found at Sfax.

In the amount of potash the Casa Grande and Palm Springs samples are also very much alike, being five to ten times richer than the Sfax samples. In the amount of phosphoric acid it is interesting to note that the Palm Springs soil, though seemingly a desert sand, contains more than twice as much of this important element as is found in the Casa Grande samples. In the potash and phosphoric acid contents either of these samples compares favorably with average agricultural soils; for instance, with the soils of the famous Michigan peach belt,[b] while in phosphoric acid the Palm Springs samples, averaging 0.436 per cent for the entire 18 inches in depth, are ahead of all but the very richest farm lands of the eastern United States. This richness of desert soils in phosphoric acid and potash is especially advantageous to olive culture, as investigations by the California Agricultural Experiment Station have shown that the olive makes much higher demands upon the soil for these elements than do grapes, plums, apricots, or oranges.[c]

HISTORY OF THE GROVE.

As nearly as can be gathered the greater part of the Pope olive orchard was set in 1890 and 1891. There was at that time an adequate supply of water available from the Whitewater ditch, which was conveyed to each block of land by box conduits. Along these conduits and across the north side of the blocks rows of cottonwood trees were set 20 feet apart. Their influence on the olive plantation will be referred to later.

The olive trees were planted 21 feet apart on the hexagonal system, giving 116 trees to the acre. For the first seven or eight years there was a fair supply of water. No Bermuda grass or other serious weed gained a foothold and the work of irrigating the trees was the chief labor. It can not be learned that during that time any fruit was produced. A resident of Palm Springs who came there in 1896 recalls that they were "expecting the trees to come into bearing the next year." About this time difficulties with the water supply began, and as nearly as can be ascertained no irrigation at all has been given the orchard since 1900.

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[a] From analyses by Mr. Joseph G. Smith, of the Bureau of Soils, U. S. Dept. of Agriculture.

[b] See Roberts, I. P., "The Fertility of the Land."

[c] Report of the Director of the California Agricultural Experiment Station, 1894–95, p. 124.

PRESENT CONDITION OF THE GROVE.

The first fact with which one is impressed on seeing this plantation is the small size of the trees considering their age. Some trees are scarcely 4 feet high, and very few more than 7 or 8 feet. Taking two average rows, the range in height was found to be from 41 inches to 98 inches, the average for 50 trees being 63.5 inches. The highest tree in the 20-acre block was found to be 9 feet, while only 10 trees could be found measuring 8 feet and upward. (See Pl. III, fig. 2.)

It is to be noticed that on these trees the branches are retained clear to the ground and that the breadth of the top exceeds the height in almost every case, so that in the 50 trees examined only one was found in which the height was greater than the breadth of top. The average breadth for the two rows is 79.5 inches as against 63.5 inches of height. These tops, too, are much branched and very compact. In nearly every case the trunk is concealed. A leafy canopy protects the trunk and main branches from the dry air and fierce heat of the desert sun.

In doing battle for their lives in the desert they have shown their ability to adapt themselves to desert methods of defense. The mesquite and paloverde,[a] the largest native trees, may attain a spread of top of 40 or 60 feet with a height of only 20 or 30 feet. The desert willow (Chilopsis) and the *Dalea spinosa*, two species somewhat less resistant to drought and heat, attain a treelike size by throwing out a defense of sprouts and low branches, or, failing in this, they are apt to show scars of severe sun scalding.

The so-called "wild apricot" (*Prunus fremontii*), venturing out a little way along the bowlder talus from the canyon's mouth, has a top so densely branched, angled, and interlocked as to well merit the name Emplectocladus, signifying interlocked branches, which now applies to the whole subgenus to which it belongs.

Similar proportions of height to spread of top will be found in nearly all of the characteristic desert shrubs, the effort seeming to be to throw as much shade and insulation as possible around the trunk and main branches.

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[a] *Cercidium torreyanum* (Wats.) Sargent.

This purpose is accomplished most effectively and in the most characteristic way of all by that typical desert tree, the majestic palm (*Washingtonia filifera*), whose dying lower leaves suspended by their long petioles form a dense thatch, completely insulating the tall, columnar, branchless trunk against both the direct and reflected heat of the sun and the drying winds. Where some vandal hand does not apply a torch, this splendid protection is retained for many years, perhaps for life.

It is probable that in the case of the olive, as well as of many native desert plants, this low, spreading canopy of top serves another purpose. Of the total precipitation for the year in these regions a considerable proportion is in the form of small showers, so that the monthly record will often be indicated by such fractions of an inch as 0.12, 0.09, 0.32, 0.06, trace, etc., these usually representing a single precipitation. Such an amount falling upon the parched soil in the open is so soon evaporated as to afford little aid to the thirsty plant. Arrested by the leaves or fine branches and carried to the ground at the base of the stem, it is so shaded and conserved as to be allowed to sink into the surface soil, where a system of short, finely branched superficial roots is ready to appropriate it. In Plate IV, figure 2, such rootlets of the olive tree are shown in natural size.

Inspection of the whole 26 acres of the plantation shows that several varieties were set, just what they were being difficult to decide with accuracy, no plat or planting list so far having been discovered. The block in which the most trees are alive and in the best condition, though not making the largest growth, has the dense, compact habit and broad top most completely developed, and here any exposure of trunk or main branches to the sun is hard to find. These trees are noticeable for the complete absence of any sun scald on the bark.

The northern seventeen rows of this block are ranker in growth and more coarsely branched, and while the leaves are larger the whole canopy is much thinner. Of this variety, probably Manzanillo, a quarter of the trees are dead and others have suffered severe sun scald. In other cases a portion of the top has died back, to be followed by a vigorous sprouting from below. Of a block of four rows adjacent to this, not 10 per cent of the trees are alive, but these appear to be of a variety little adapted to these conditions.

The cottonwoods already referred to, bounding the 20-acre block on the west and north sides, are all dead, but so also are the olive trees next to them. Of the Manzanillo olives, the two rows on the north and next to the cottonwoods are two-thirds dead, while the third row is in bad condition. Of the trees on the west ends of the rows next to the cottonwoods in the larger block not so large a proportion is dead, but those alive are small and in bad condition. Figure 6 shows very distinctly the effect of the cottonwood growth on the olives. The struggle has been so intense for a bare survival on the part of the whole plantation that the competition with a powerful feeder like the cottonwood has proved fatal, though the cottonwoods probably survived the olives but a few years.

Crossing the conduit to the next 20-acre block, only half of which was set, are two small blocks of olives, 6 acres in all, with 4 acres of figs between them. Here the contrast between the green of the olives on either side and the figs, which are dead save a few struggling sprouts, illustrates in a most marked way the comparative drought resistance of the two. Indeed, of exotic trees on this ranch only the pepper trees bordering one field show an ability to endure these extreme conditions equal to that of the olive.[a]

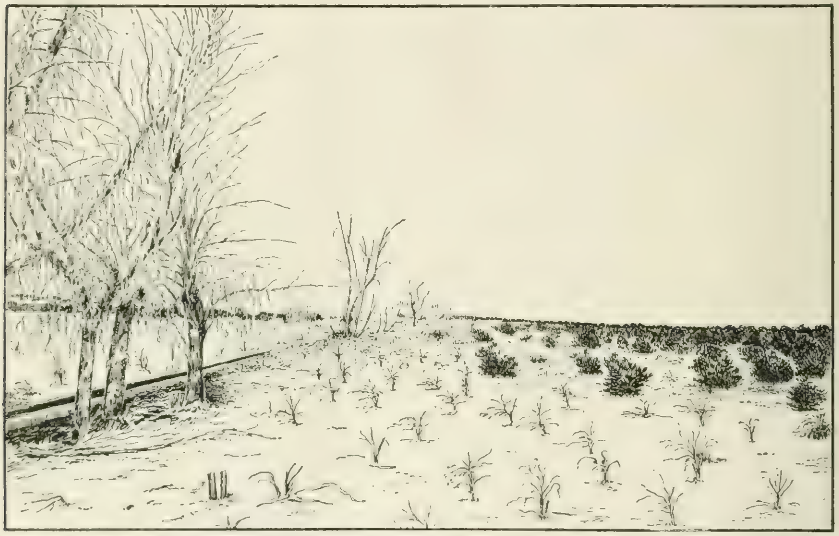

FIG. 6.—Olive trees which have died through competition with a row of cottonwood trees on the Pope olive plantation, near Palm Springs, Cal. (From a photograph.)

While trees of this slow growth and evergreen nature are consequently slow in forming what the foresters call dominant and suppressed classes, a close inspection of this grove shows such a work to be in progress, not as is generally the case in a forest by the process of dominant trees overtopping and shading the weaker ones, but by means of dominating root systems by which once a tree has gained the ascendancy in water appropriation it will sooner or later have three or four adjacent trees in the suppressed class. This suppression of the weak trees by the stronger rooted dominant ones begins as soon as the roots meet in the intermediate territory, which has happened in many instances in this grove and seems to account for the death of many of these trees and the weak condition of others. This affords conclusive proof that olive trees can not be grown successfully 21 feet apart under light rainfall without ample irrigation, and, what is more significant, that when given wide planting they are capable of extending their root systems and collecting their water supply from a very wide area.

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[a] A visit was made to this plantation on April 13, 1908, at which time about 20 per cent of the trees of the more resistant variety of olives was in blossom, but at a later visit, June 11, not a single fruit could be found to have set. On the same date two olive trees in Dr. Wellwood Murray's irrigated garden in Palm Springs village were carrying fair crops of fruit.

OLIVE ROOT SYSTEMS ADAPTED TO UTILIZE LIMITED RAINFALL.

The remarkable endurance of drought displayed by the olive trees of which an account is given in this paper, but especially by those at Palm Springs, Cal., must be explained (1) by unusual ability to collect moisture from a soil supply normally deficient and (2) by an ability to conserve that moisture and perform their physiological work on a supply that would prove totally insufficient for ordinary trees. For the first we must look to the roots, and as these were uncovered and plotted it became evident that the deeply penetrating system possessed by the mesquite for bringing up water from a subterranean source was not possessed by the olive, nor would it have availed much, as on near-by land a well had been sunk to a depth of 80 feet, disclosing only dry cobblestone and gravel. No penetrating taproots were found, but usually each tree had a deeply-seated burl or swelling two or three times the diameter of the trunk above ground, from which radiated evenly in all directions a strong set of roots running off nearly horizontally. Plate IV, figure 1, shows the trunk, burl, and main roots of a tree which was selected for study from the most resistant variety of the Pope plantation.

This tree was barely 6 feet in height, with a top spread of 7 feet and a trunk diameter of 3¾ inches; yet we find a root system radiating to 10 and 11 feet in nearly all directions and having a total length of roots of one-eighth of an inch in diameter and upward of about 185 feet. The length of roots was at least double that of the twigs and branches of similar diameter, while the area occupied by the roots was nine times that of the spread of the branches.

The strongly gnarled burl was a foot in depth, and from this the roots issue at depths of 2 to 10 inches. With but a few exceptions they all break up into fine rootlets at depths of 5 to 8 inches, the greatest number being at 6 inches. In two cases small laterals penetrate to 18 inches in depth, and there was a curious case of branches from two separate roots going down at the same point—possibly an old burrow of some rodent affording a more mellow soil—to 36 and 42 inches, respectively, beyond which point they were not excavated and were still one-eighth of an inch in diameter.

The block of the Manzanillo variety at the north end of the 20 acres showed a different behavior from that of the main body of the grove. The wood growth averaged much ranker, but the branches were coarser and the tops more open to the sun. Far less adaptability to conditions is evident. Dead trees, trees with dead tops but with live sprouts from below, dead branches, and sun-scalded spots on exposed places are to be seen on every side. In this block the tree selected for study was 8 feet high, with 8 feet spread of top and a trunk 5 inches in diameter. A still stronger root system was found here, there being ten roots of from three-fourths of an inch to 1½ inches in diameter springing from the burl at the following depths below the surface: Two at 2 inches, one at 3 inches, one at 12 inches, three at 14 inches, two at 16 inches, and one at 18 inches. It being evidently impossible to keep track of all of these at one excavation the surface roots were excavated by themselves. These comprised three strong roots, issuing at 2 and 3 inches below the surface, and a circle of short fine roots, which the writer called the shade roots from the fact that they occupy the space immediately beneath the spread to the top.

Figure 7 shows these superficial roots represented in solid lines, while the deeper roots are shown by dotted lines, but it should be noticed that a number of the shallow roots figured came up to join this class from roots of deep origin. These shallow roots taken together may be regarded as a very important part of the equipment of the tree. Their rootlets reach to quite near the surface, so that they are prepared to gather moisture from a small rainfall. The shade roots appear to collect also the water which is arrested by the top and runs off to the ground from the trunk. It must be remembered that the medium in which these trees grow is so nearly pure sand as scarcely to be called a soil. There is a good deal of fine material in it, but it does not bake or pack, and cracks never occur. It is very doubtful whether any method of soil culture, dust mulch, or subsurface packing would be of value here. All that such treatment is expected to accomplish is already insured by the nature of this soil, and, furthermore, any cultivation would only destroy these delicate rootlets so nicely adapted to taking advantage of the lightest rainfall. Referring to the deeper roots in figure 8, we notice first the large area occupied by them as compared with the spread of the top. The roots of this tree over one-eighth of an inch in diameter have a total length, including the upper layer, of approximately 376 feet. The area of the root spread, as compared with the spread of the top, would be a little more than 7 to 1.

The depth of the course followed by these large roots of 12 to 18 inches is a very marked feature. Most interesting is the deep penetration, almost vertically, of branches from many of these roots to depths of 2, 3, 4, and even 5 feet, where they were left, owing to the difficult nature of the digging. In most cases gravel and cobblestones of considerable size were encountered at these depths, and as

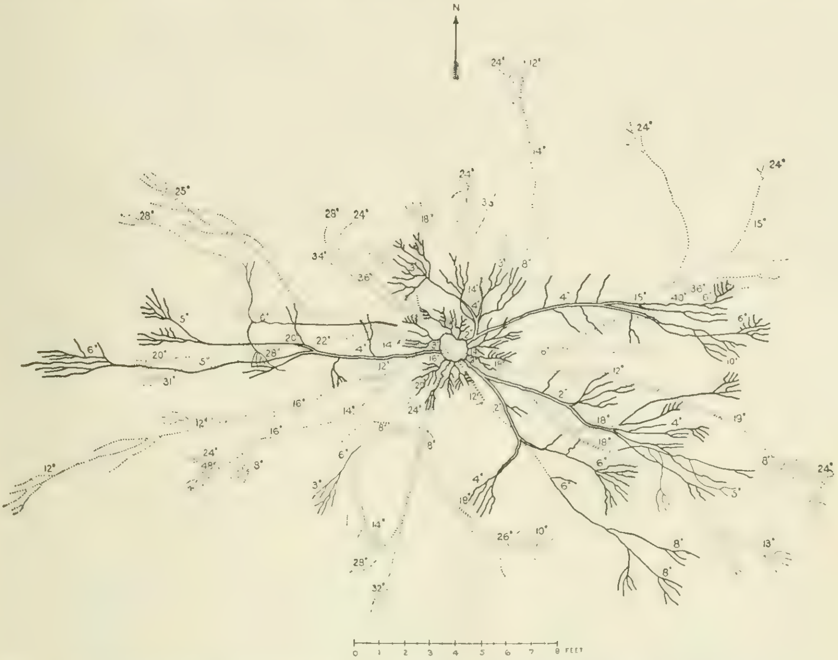
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FIG. 7.—Diagram showing the distribution of superficial roots (solid lines) and deep roots (dotted lines) of a Manzanillo olive tree on the Pope olive plantation, near Palm Springs, Cal.

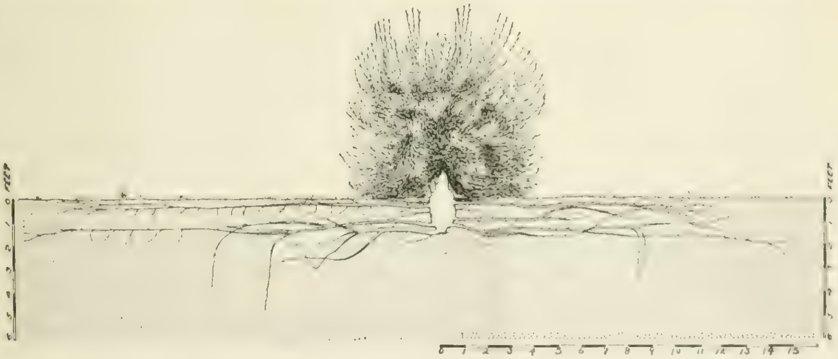
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FIG. 8.—Diagram showing the root system of a typical dry-land olive tree on the Pope olive plantation, near Palm Springs, Cal., showing the position and distribution of the roots in the soil.

these were all old, hard roots it seems probable that they had gone down to these depths during the years when the orchard was still irrigated. The rootlets branching from these and all the deeper lying roots were much fewer than those nearer the surface.

A point previously referred to of special interest in this study is that of a number of deep-lying roots at points several feet from the tree sending off branches which rise suddenly to the level of 4 to 8 inches, along which levels they make a growth of several feet, sending off numerous branchlets and small feeding rootlets. These ascending laterals were found to show but three or four rings of annual growth while the main root (though it was impossible to count the rings accurately) was several years older. Evidently the upper growth had been made since irrigation ceased in an effort to reach the more favorable conditions for moisture and air at the upper level. In both trees studied, as well as in many others where small excavations were made, fine-feeding rootlets were found in considerable numbers at 2 to 24 inches in depth, but the zone of their greatest abundance was at 4 to 10 inches. Plate IV, figure 2, shows a section of a long root from a depth of 6 inches, with lateral branches and feeding rootlets, from a photograph of exactly natural size.

MOISTURE ECONOMY AIDED BY THE STRUCTURE OF THE OLIVE LEAF AND STEM.

In addition to the elaborate arrangement of olive roots for collecting the last particle of moisture possible from a sandy desert soil, there must still exist a remarkable economy in tissues and functions to enable a tree to survive, not to say to make growth, under such conditions.

It is to the leaves that we must look chiefly for this work. Their narrow form, reflexed margins, thickness, and tough leathery texture, as well as the densely hairy, almost felted under surface, all indicate that they are prepared to resist to the extreme the drying influence of the desert air. The minute anatomy of the leaf and stem of the olive has received considerable attention from botanists, but apparently no attempt has hitherto been made to ascertain to what extent different environments affect modifications of structure. That some light might be had on this most interesting point, material was procured by the writer of this bulletin from olive groves of California and Arizona, the samples being obtained from such widely diverse environments as the moist, fog-laden air and ample irrigation of Niles, near the San Francisco Bay, and the extreme of desert dryness and heat of Palm Springs, Cal. These were placed in the hands of Dr. Theodore Holm, whose study of them, illustrated in Plate V, figures 1 and 2, and five text cuts, is given in the Appendix to this bulletin.

SUCCESSFUL DRY-LAND OLIVE CULTURE IN CALIFORNIA.

In contrast with the mere endurance test of which the preceding examples are very instructive illustrations, there is in the so-called "inside" region of southern California, between the ocean and the mountains, an olive industry based on the local rainfall on lands above canal lines or lacking a sufficient water supply. Excellent examples of this type of olive culture may be found in the neighborhood of Beaumont, Riverside County; La Mirada, Orange County; Chatsworth and San Fernando, Los Angeles County; in Santa Barbara County; and also in the more northerly part of the State near Oroville.

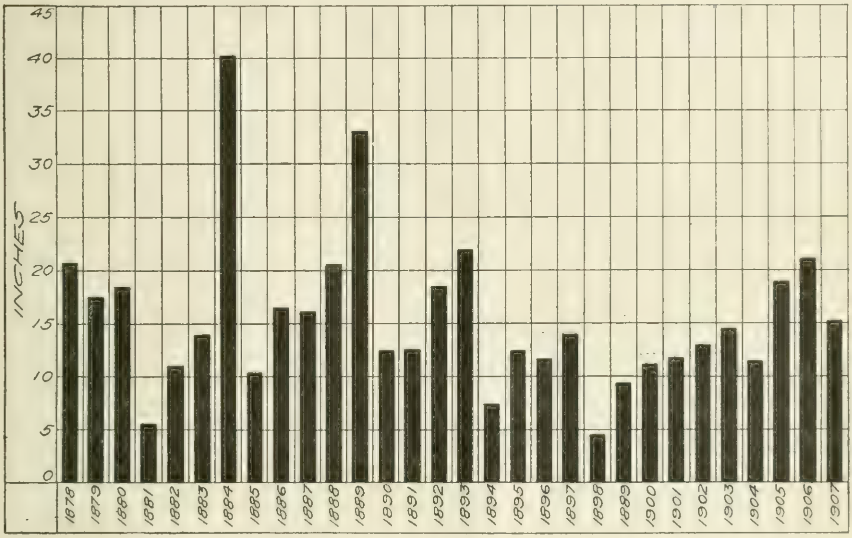

FIG. 9.—Diagram showing the annual rainfall at Los Angeles, Cal., as presented in Table VI.

While varying considerably in their climatic conditions they all agree in these general features: A minimum temperature never below 20° and seldom lower than 28° or 30° F.; a maximum summer temperature of 105° in cooler seasons to 114° F. in extremely hot years, but with a monthly mean temperature not below 48° in winter and seldom exceeding 80° F. in summer. From a study of Table VI, represented graphically in figure 9, we may see that the annual rainfall at Los Angeles has exceeded 12 inches during more than half of the years recorded, occasionally rising to 22 or 23 inches, or even higher, and only in rare years of drought falling as low as 7½ inches, with the minimum of 4.83 inches during the thirty years recorded.

TABLE VI.—*Annual rainfall at Los Angeles, Cal., 1878 to 1907, inclusive.*[a]

Year.	Inches.	Year.	Inches.
1878	20.86	1893	21.96
1879	17.41	1894	7.51
1880	18.65	1895	12.55
1881	5.53	1896	11.80
1882	10.74	1897	14.28
1883	14.14	1898	4.83
1884	40.29	1899	8.69
1885	10.53	1900	11.30
1886	16.72	1901	11.96
1887	16.02	1902	13.12
1888	20.82	1903	14.77
1889	33.26	1904	11.88
1890	12.69	1905	19.19
1891	12.84	1906	21.31
1892	18.72	1907	15.30

[a] For the data used on the climate of California, the writer is indebted to Mr. A. B. Wallaber, of the Climate and Crop Service of the United States Weather Bureau at Los Angeles, Cal.

TABLE VII.—*Mean relative humidity at Los Angeles, Cal.*[a]

Month.	5 a. m.	5 p. m.	Month.	5 a. m.	5 p. m.
January	67	64	August	87	63
February	73	63	September	82	63
March	80	65	October	78	68
April	82	63	November	64	65
May	87	65	December	61	64
June	87	61			
July	90	62	Year	78	64

[a] For the data used on the climate of California, the writer is indebted to Mr. A. B. Wallaber, of the Climate and Crop Service of the United States Weather Bureau at Los Angeles, Cal.

The rainfall of this region is enhanced by frequent coast fogs. The mean relative humidity from month to month is an important factor in all such cultural problems, but this is obtainable only for Los Angeles, with which point we may fairly compare Los Angeles County and Orange County. This, it will be seen from Table VII, ranges from 61 to 90 per cent for the 5 a. m. observation, and from 61 to 68 per cent for the 5 p. m. observation. This condition of atmospheric moisture would give orchards in these localities a great advantage, for instance, over the one studied at Palm Springs in the edge of the Colorado Desert, except that the trees suffer more from the attacks of parasites in the more humid climate.

One of the most extensive examples of olive culture without irrigation in this region is to be found on a large ranch in the southern part of Los Angeles County, near La Mirada, Cal. Here are 500 acres in olives, the oldest set sixteen years ago and others as recently as seven or eight years ago. The planting distance was only 20 feet, giving 108 trees to the acre. The olives occupy rolling hillside land for the most part, difficult of irrigation even if a water supply were at hand. The soil is as a rule a rather strong adobe, with some admixture of sand in parts of it. The nature of the hills nearest would indicate an abundance of lime in this soil, which is so important for olive production. Some degree of cultivation is given between the rows, but with the older trees the spread of the branches prevents reaching all of the surface.

The original plan was to remove half of the trees as they began to crowd by cutting out every other row on the diagonal. The effect of this is to leave one-half, or 54 trees to the acre, in rows 20 feet apart, and trees 40 feet apart in the row alternating. This has been done with some blocks of the older trees and is a very evident gain. Where the original stand of the older trees still remains there is evidence of crowding and lack of thrift in many cases, and the writer is convinced that a stand of only 27 trees to the acre, or 40 by 40 feet, would be still better as the trees advance in age. The great vigor and productiveness of the trees along the draws and low places where any surplus of rain would flow give evidence that water famine had been felt by the small trees.

A notable feature of this orchard was the prevalence of the common black scale, a parasite found on olive trees all along the range of the ocean fogs unless vigorously combated, and not found to a harmful extent in the interior valleys of California or Arizona. How seriously this scale interferes with the functions of the tree is a matter upon which olive growers differ widely, but there is no difference of opinion as to the scale preventing the production of an olive of good pickling qualities.

Of the varieties planted, the Mission is the most prominent and satisfactory, though considerable blocks of the Nevadillo, the Pendulina, and the Columbella are also grown.

Plate VI, figure 1, shows a general view across a small valley in this orchard, and figure 2 a view among the rows of older trees thinned by removing alternate diagonal rows.

In comparison with this orchard stands the case of a ranch 2 or 3 miles away, the soil and location being practically the same. Here 400 or more acres of olives, probably differing little at the start, have for several years been in absolute neglect. Many of the trees were never properly headed up, being mere stools of several shoots from the ground. No evidence of cultivation could be seen, but grass, weeds, and small shrubs robbed the trees of the needed moisture. This, with the close planting, had reduced the problem to one of existence instead of profitable production. There was some fruit, and occasional trees enjoying some little advantage in space and moisture were bearing fair crops. These only helped to prove the fallacy of the idea that the olive is a tree that may be planted upon dry and barren soil, given absolute neglect, and yet produce profitable crops of fruit. Here in these contrasted orchards, with soil, rainfall, and temperature similar, the difference between pruning and culture on one hand and neglect on the other made the difference between a profitable industry with a fine product and a poor and scant crop not worth going over the ground to gather.

AREA OF POSSIBLE DRY-LAND OLIVE CULTURE IN THE UNITED STATES.

AREA LIMITED BY THE MINIMUM TEMPERATURE.

Of the factors defining the area of olive culture in the United States, that of minimum temperature is the most important.

It has been claimed by some authors [a] and by many olive growers that an actual minimum temperature of 14° or 15° F. will prove fatal to the olive tree. It is undoubtedly true, however, that the olive will endure considerably more cold than this if it is in a thoroughly dormant condition. This is especially true where the atmosphere is dry and where the low temperature persists for only a short time, possibly a few minutes at near daylight, as is so often the case in the southwestern sections.

As an illustration of these ideas, in 1899,[b] from February 11 to 13, a cold wave of unusual intensity swept over a great portion of the Southwest, temperatures of $-6°$ to $-23°$ F. being recorded in northern Texas, and as low as 8° F. in the southwest border.

At San Antonio two stations gave minimum records of 4° F. At Fort McIntosh, on the Rio Grande near Laredo, a minimum temperature of 5° F., probably for only a brief period, was recorded on the morning of February 12, and at Fort Ringgold, 90 miles down the river, a temperature of 7° F. was recorded on the morning of February 13.

An olive grove of an acre or more about 2 miles from Fort McIntosh suffered some killing back, though the trees were not seriously injured and may be seen to-day looking as vigorous as any in the olive-growing districts of California or Arizona.

At the dry-land experiment station of the Bureau of Plant Industry, near San Antonio, Tex., young olive trees of the Chemlali variety endured a minimum temperature during the winter of 1907–8 of 18° F., with but a slight killing back at the tips. Yet in 1909 these olive trees and trees of several varieties planted in 1908 were with one exception killed to the ground under conditions where the minimum temperature reached was only 18° F. After mild weather during the latter part of December and the early part of January, with maximum temperatures of 76° and 77° on January 9 and 10 and 63° F. on the following day, a "norther" brought the temperature to 20° at 3 p. m. on January 11, with a minimum of 18° F. at night. On January 12 the minimum was 18° with a maximum of only 22°, and there was a minimum of 22° on the morning of January 13, the temperature thus being maintained about forty hours at from 10° to 14° below freezing. These trees were in a plat which in accordance with the general cultural policy of the farm had been kept under fine surface tillage, enabling the soil to store abundant moisture from the season's rains. This arrangement prevented the olive trees from entering the dormant condition necessary to their resisting the low temperatures, and the freezing sap burst the bark of most of them and killed all to the crown, from which they sprouted again freely.

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[a] A temperature of 5° C. below zero (or 23° F.), followed by a sudden thaw operated by the sun's rays, is sufficient to kill it totally at the base. With a lower temperature not followed by sunny days the plant does not suffer as much, as it can stand a cold of 10° C. below zero (or 14° F.).—*Olive Culture, Italy, Annual Report of the State Board of Horticulture, California, 1890, p. 449.*

"A low temperature, say 14° F., is fatal to the tree."—*B. M. Lelong, Investigation Made by the State Board of Horticulture of California Olive Industry, Sacramento, 1900, p. 8.*

"The olive can grow in all regions where the minimum temperature does not fall below $-7°$ or $-8°$ C. and does not last more than eight days."—*Translation from Hidalgo Tablada.*

[b] Annual Summary, 1899, Texas Section, Climate, and Crop Service, Weather Bureau, U. S. Dept. of Agriculture.

At Boerne, 30 miles northwest of San Antonio and 700 feet higher in altitude, the temperatures registered were 1° lower each day of this cold spell than those at the San Antonio farm, yet the olive trees there sustained much less injury.

A region may have monthly mean temperatures and an annual mean sufficient to place it high in the scale when compared with well-known olive regions, yet where high winter means include sudden drops and low minima the trees will suffer all the more severely. As an example, the monthly mean temperatures at San Antonio are higher throughout the year than those of Fresno, Cal., or of Catania, in Italy, and excepting only the autumn months, higher than those of Sfax, in Tunis, three representative olive-producing regions. Yet the liability to the sudden advance of cold waves may upon experimentation be found to exclude this portion of Texas entirely from the olive-growing belt.

It seems probable also that there is a considerable difference in olive varieties in resistance to cold, and an inviting field for experimentation is here offered.

The high altitudes of the greater portion of New Mexico will doubtless exclude the olive on account of too severe cold. However, it seems probable that favored mesa sites may be found in the southwestern portion of the Territory, particularly in Grant and Dona Ana counties, where the olive may be grown.

French authorities[a] give the maximum range in altitude for the olive as from 500 meters (1,600 feet) in France and northern Italy to

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[a] Investigation Made by the State Board of Horticulture of the California Olive Industry, Report to Governor Gage, 1900, p. 8.

700 meters (2,300 feet) in Sicily, it being even affirmed that it ascends as high as 800 meters (2,600 feet) on that island.

Simmonds, in his "Tropical Agriculture," states that the olive grows at Quito, under the equator, at a height of 8,000 feet above sea level.[a]

According to the reports of the California State Board of Horticulture[b] the olive does well at an altitude of 3,000 feet at 37 degrees latitude in the Sierra Nevadas. In the southern part of Arizona it is probable that it may thrive at still higher altitudes, possibly at 5,000 feet. Nor could a safety line of altitude alone be defined, for some higher spots favorably situated will be found to be more reliable than lower locations adjacent.

In California the olive grows well around San Diego, and from there along the coast northward to the upper end of the State and up into small valleys of the Coast Range. Farther inland the success would be limited by altitude, but it can be depended upon throughout upland portions of the greater area of the interior valleys and to altitudes of about 3,000 feet in the foothills. In Arizona areas of olive territory may be looked for as far north as the Gila River in Pinal County and farther west to the north line of Maricopa County, with probably the western limit at about the meridian of Gila Bend, on account of reduced rainfall. (See Table VIII.)

TABLE VIII.—*Localities in Arizona where dry-land olive culture may be possible, with meteorological record.*[c]

Station.	Length of record.	Altitude.	Mean annual temperature.	Minimum for 1908.	Date of killing frost, 1908.		Precipitation, 1908.
					Spring.	Fall.	
	Years.	*Feet.*	° *F.*	° *F.*			*Inches.*
Congress	12	3,668	67.2	29	Feb. 4	Nov. 9	13.15
Columbia	10	1,900	68.2	29	Feb. 16	Nov. 25	15.40
Kingman	7	3,362	61.2	22	June 4	Oct. 18	11.77
Jerome	12	4,743	60.8	22	Apr. 17	Sept. 29	18.32
Cline	9	2,300	63.9	23	Apr. 9	Oct. 24	15.94
Globe	6	3,525	62.9	24	Mar. 28	Oct. 19	16.51
San Carlos	19	2,456	....	23	Apr. 4	Oct. 21	12.78
Phoenix	14	1,108	69.5	30	Mar. 8	Dec. 21	[d]7.88
Dudleyville	18	2,360	65.0	24	Mar. 23	Oct. 22	14.60
Tucson	28	2,390	67.5	22	...do....	Oct. 19	10.69
Benson	25	3,523	66.1	21	...do....	...do....	9.03
Oracle[e]	16	4,500	62.0	10	Mar. 29	Dec. 4	25.90
Tombstone	10	4,550	62.1	25	Feb. 28	Nov. 18	14.00

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[a] "In the neighborhood of Quito, situated under the equator, at a height of 8,000 feet above the level of the sea, where the temperature varies even less than in the island climates of the temperate zone, the olive attains the magnitude of the oak, yet never produces fruit."—*P. L. Simmonds, Tropical Agriculture, p. 393.*

[b] Investigation Made by the State Board of Horticulture of the California Olive Industry, Report to Governor Gage, 1900, p. 8.

[c] Annual Summary, 1908, Arizona Section of the Climatological Service of the Weather Bureau.

[d] Mean annual, Weather Bureau, U. S. Dept. of Agriculture.

[e] Climatology of the United States, Bulletin "Q," Weather Bureau, U. S. Dept. of Agriculture.

AREA LIMITED BY HEAT REQUIREMENTS.

While the Pope olive grove has been studied as a case of survival without fruiting in spite of extreme adverse conditions, yet in the garden of Dr. Wellwood Murray at Palm Springs Hotel, with an ample shelter belt of trees around the border, two trees of the Pendulina variety have made a good growth and ripen fair crops of fruit with only scant irrigation, though there is scarcely a summer when a temperature of 120° to 122° F. is not recorded.

As to the maximum temperature which the olive will withstand, it is hard to find a locality in the United States where a fair degree of success may not be met with.

Contrary to the often-expressed opinion that it is only successfully grown in regions adjacent to the seacoast[a] the olive thrives and produces abundantly in such hot interior localities as Biskra, Algeria; Fresno, Cal.; and Phoenix, Ariz.

At Phoenix, Ariz., maximum summer temperatures of 112° to 116° F. are matters of record, with a July mean of 90° F. The mean temperatures for the months of June, July, August, and September are 6 to 9 degrees higher than those of Catania, the warmest olive-growing station of Italy,[a] and compare quite closely throughout the year with the mean of Biskra, Algeria. (See fig. 10.)

There is near Phoenix a small but flourishing olive industry under irrigation, the trees making a rapid, healthy growth and bearing good crops of olives, yielding oil of an excellent quality. This affords proof of the high temperature which the olive will sustain when that factor alone is taken into account.

There is an area through the more wind-exposed portions of the Colorado Desert where it is possible that the hot, dry winds of the early spring prevent, as a rule, the setting of the fruit, though the few trees to be found there make a fair growth with a minimum of irrigation.

For the development of the olive fruit a rather constant number of heat units above the dormant or zero point of the olive tree is needed during the active or growing season. For convenience in transcribing the data from weather records, however, these heat units are here assumed in degrees above zero, Fahrenheit. Thus, as the mean temperature of Phoenix, Ariz., has been determined after a number of years of recorded observations to be 52° F. for the month of January, multiplying 52 by 31, the number of days, gives 1,612, representing the number of heat units for that month. Computing each month in the same manner, their sum amounts to 25,607, the number of heat units for the year.

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[a] Caruso, G. Dell' Olivo, Turin, 1883, p. 34.

Table IX shows the mean monthly and mean annual temperatures, with the sums of heat units for twelve localities of the olive-growing regions of Europe, Africa, and the United States, selected to show a range of temperatures from that at Bologna, Italy, with an annual mean of 57.16° F. and 20,895 heat units, which is slightly too cool, to that of Palm Springs, Cal., where there is probably about the extreme of heat which the olive will endure, it having an annual mean of 72.1° F. and a summation of 26,349 heat units.

TABLE IX.—*Mean temperatures and summation of temperatures, by months, at points in Algeria, Tunis, Sicily, Italy, Arizona, and California.*

Month.	Palm Springs, Cal.		Biskra, Algeria.[a]		Phoenix, Ariz.		Tucson, Ariz.		Sfax, Tunis.[b]		Catania, Sicily.[c]	
	Mean.	Summation.	Mean.	Summation.	Mean.	Summation.	Mean.	Summation.	Mean.	Summation.	Mean.	Summation.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
January	56.20	1,742	50.5	1,565.5	52	1,612	50	1,550	51.3	1,590.3	50	1,550
February	57.50	1,610	53.0	1,584.0	56	1,568	54	1,512	54.4	1,523.2	52	1,456
March	63.96	1,983	60.5	1,875.5	60	1,860	59	1,829	59.1	1,832.1	56	1,736
April	68.62	2,059	68.0	2,040.0	67	2,010	66	1,980	63.2	1,896.0	60	1,800
May	74.19	2,300	75.0	2,325.0	75	2,325	74	2,294	68.8	2,132.8	68	2,108
June	85.06	2,552	82.0	2,460.0	85	2,550	82	2,460	72.8	2,184.0	76	2,280
July	91.55	2,838	93.2	2,889.0	90	2,790	88	2,728	78.5	2,433.5	81	2,511
August	88.23	2,735	90.0	2,790.0	89	2,759	86	2,666	79.3	2,458.3	82	2,542
September	83.73	2,512	87.5	2,625.0	83	2,490	81	2,430	78.4	2,352.0	77	2,310
October	76.48	2,371	75.0	2,325.0	71	2,201	70	2,170	72.8	2,256.0	68	2,108
November	63.93	1,918	61.0	1,830.0	61	1,830	59	1,770	61.8	1,854.0	60	1,800
December	55.88	1,729	53.0	1,643.0	52	1,612	52	1,612	54.0	1,674.0	54	1.674
Year	72.10	26,349	70.7	25,952.0	70	25,607	68	25,001	66.2	24,186.2	66	23,875

Month.	Fresno, Cal.		Los Angeles, Cal.[d]		San Diego, Cal.		Pisa, Italy.[c]		San Jose, Cal.		Bologna, Italy.[c]	
	Mean.	Summation.	Mean.	Summation.	Mean.	Summation.	Mean.	Summation.	Mean.[e]	Summation.	Mean.	Summation.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
January	45	1,359	54.2	1,670.2	54	1,674	44	1,364	48	1,488	36	1,116
February	51	1,428	55.5	1,554.0	55	1,540	49	1,372	51	1,568	42	1,176
March	54	1,674	56.9	1,763.9	56	1,736	52	1,612	54	1,674	48	1,488
April	60	1,800	59.4	1,782.0	60	1,800	60	1,800	56	1,680	58	1,740
May	67	2,077	62.5	1,937.5	62	1,922	65	2,015	60	1,860	65	2,015
June	75	2,250	66.7	2,001.0	65	1,950	71	2,130	66	1,980	72	2,160
July	82	2,542	68.9	2,135.9	68	2,108	77	2,387	67	2,077	78	2,418
August	81	2,511	71.4	2,213.4	70	2,170	75	2,325	67	2,077	74	2,294
September	74	2,220	69.5	2,085.0	66	1,980	72	2,160	65	1,950	69	2,070
October	64	1,984	64.7	2,005.7	64	1,984	62	1,982	60	1,860	58	1,798
November	55	1,650	60.4	1,812.0	59	1,770	52	1,560	54	1,620	46	1,380
December	46	1,426	56.5	1,751.5	56	1,736	50	1,550	50	1,550	40	1,240
Year	63	22,921	62.3	22,712.1	61	22,370	60.75	22,257	58	21,384	57.16	20,895

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[a] From Bulletin 53, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 61.

[b] From Bulletin 125, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 14.

[c] From "The Olive, Its Culture in Theory and Practice," by A. T. Marvin, San Francisco, 1888.

[d] Computed from data furnished by Mr. A. B. Wallaber, United States Weather Bureau, Los Angeles, Cal.

[e] Mean temperatures from "Climatology of the United States," Bulletin "Q", Weather Bureau, U. S. Dept. of Agriculture.

Caruso[a] states that the olive sap begins to stir at a temperature of 10.50° to 11° C. (which is equivalent to 51° to 52° F.) and flowers at 18° to 19° C. (equivalent to 64.4° to 66.2° F.). According to this author, we must regard the zero point of the olive as about 51° to 52° F., but the temperature figures in Table IX indicate that for such localities as Palm Springs and Los Angeles in California and Phoenix and Tucson in Arizona the zero point must be somewhat higher, probably 55° to 56° F.

To ripen the fruit within a period of safety from autumn frosts, there must be a sum of about 16,400 heat units within six or seven months from the starting of vegetation. Allowing seven months this would be equivalent to about 16,400 units from, say, the middle of March. In order to correlate this seasonal estimate with the summation of average annual heat units, as shown in Table IX, we will add to the above sum the number of heat units from January 1 to March 15 for Pisa, Italy, a typical olive locality, and we have a summation of 20,070 units, which would throw the olive ripening at Pisa to about November 20.

Hidalgo Tablada[b] gives the temperature for the flowering of the olive at 19° C. (66.2° F.) and states that at Seville this is reached about May 1. From that statement, the accumulation of 3,978 units C. (12,376 F., allowing one hundred and sixty-three days) is sufficient to mature the fruit, which will be accomplished early in October, after a growing season of 27.3° C. (81.14° F.) mean temperature. These dates of seasonal activity of the olive can be regarded only as approximations, there being variations due to localities as well as to varieties of fruit.

Data regarding the olive in relation to climate in the United States are rather meager, but what we have coincide in a very interesting way with the European observations.

Figure 10 is a graphical showing of the data of Table IX, summing up the heat units in columns for each locality, the monthly summations being carried between the heavy black lines across the chart. The heavy dotted horizontal lines show approximately the seasonal activity of the olive as it relates to these summations.

The phenological records for the olive at Phoenix, Ariz.,[c] for the year 1907–8 show the average date of full bloom of the olive to be about May 1, at mean temperatures of 66° to 71° F., shown by line *C*, figure 10.

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[a] Caruso, G. Dell' Olivo, Turin, 1883, p. 34.

[b] Hidalgo Tablada, José de. Tratado del Cultivo del Olivo en España y Modo de Mejorarlo, Madrid, 1899, p. 74.

[c] See the phenological records for Phoenix, Ariz., for December, 1907 and 1908, in the Arizona section of the Climatological Service of the Weather Bureau, U. S. Dept. of Agriculture.

The olive harvest is noted as beginning from October 8 to 10 and as completed during the latter part of December. The growing period from flower to earliest ripe fruit averages one hundred and sixty-three days at a mean temperature of 81.6° F., giving a summation of 13,314 units, which corresponds very closely with the figures of Caruso and Tablada. Adding the means, 7,050 units from January 1 to May 1, we have a total of 20,364 units.

For the full maturing of the crop of medium varieties, 24,000 to 25,000 units will be needed at this station, while late-maturing sorts will not ripen till well into the winter. Referring to the diagram (fig. 10) the line *D* indicates 20,364 units, which occur early in October for Phoenix, late in November for Los Angeles and Fresno, and barely within the year at Bologna, Italy. Caruso states that the latter place is too cool for the olive, on account of the frosts of December and January, but that the fruit matures in sunny localities on the hillsides not far from the town. In localities having low summer means but with little or no frost in the winter months, such as San Jose and Santa Barbara, Cal., where the requisite number of heat units for the first ripening of the fruits will barely be accumulated by the end of December, the olives may remain on the trees throughout the succeeding winter months. Where the summation of about 21,000 degrees can not be reached before such low autumn temperatures prevail as will injure the fruit, olive growing should not be undertaken.

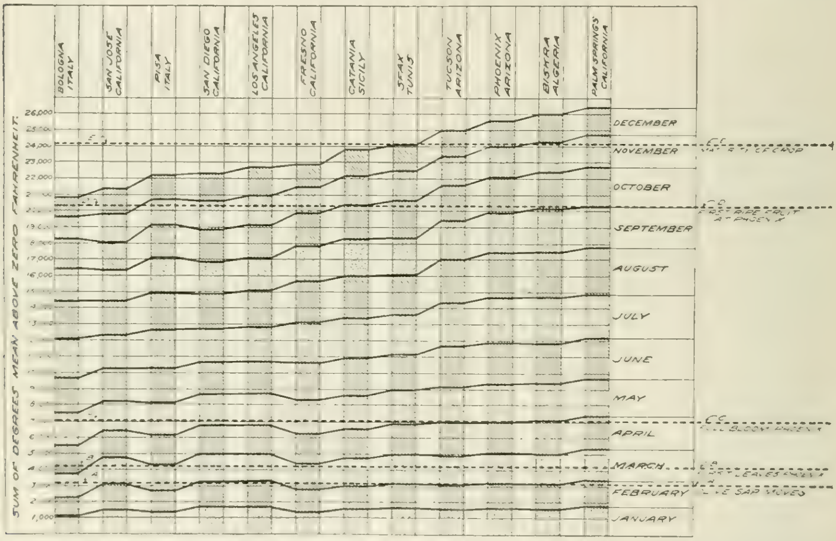

FIG. 10.—Diagram showing the monthly means and summation of heat units of places in the olive-growing regions, illustrating the seasonal activity and heat requirements of the olive, arranged from Table IX.

AREA LIMITED BY RAINFALL.

Taking up the consideration of rainfall, the industry must be considered from a different standpoint from that in which olive growing has been viewed in this country in the past. The usual planting distance has been from 20 to 24 feet. With abundant water the trees might prosper and produce remunerative crops with this area to draw from. When dependent upon local rainfall they have shown signs of failure.

In the valuable pamphlet on olive culture entitled "Investigation Made by the State Board of Horticulture of the California Olive Industry, Report to Governor Gage," 1900, page 29, is found a very significant discussion of the water problem by the Hon. Frank A. Kimball, the substance of which is as follows: Olive trees set at the ordinary orchard distance in this region, usually about 116 trees to the acre, gave during their earlier years very excellent results without irrigation. The growth was vigorous and the fruit large and fine.

Mr. Kimball gives a graphic account of their condition a few years later, as follows:

> The trees on becoming large required the necessary moisture to develop their growth, which had now assumed immense proportions. The soil could not furnish the requirements of the trees, and in the summer they lost the larger portion of their leaves. They remained in this semidormant condition until the rainy season set in or moisture from the soil began to rise. Most of the fruit dropped, and what did not fall did not attain a size suitable for picking. This condition of affairs continued until the growers resolved to apply water. After a season or more of demonstration they found irrigation to be one of the essential means through which a crop of fruit can be assured.
>
> The reason why we do not get olives is, the trees are starved, if want of water can be called starvation. For lack of water the soil can not furnish the material from which the olive is made.

The idea that the olive trees need a certain minimum volume of water for the performance of their physiological work is a fundamental one, but it does not seem to have occurred to these growers that by reducing the number of trees to the acre, thereby giving to each tree a sufficient area to afford the needed moisture, the same results might be secured as by irrigation. The olive has shown its ability to send out a root system that will secure the needed moisture from the larger area of soil and maintain a high productiveness. This has been shown by Mr. T. H. Kearney's study of the dry-land culture of the olive in Tunis, now accessible in Bulletin 125 of the Bureau of Plant Industry. From this publication we learn that a great olive-oil industry is carried on in Africa on lands receiving normally only from 9.3 to 15 inches of rainfall annually, while several good crops were produced during a period of seven years when the rainfall averaged only 6 inches, according to the French records.

The secret of this lies in wide planting, not more than 11 trees to the acre, and in clean cultivation, keeping the soil in a condition to receive every drop of rainfall and to conserve it to the utmost, the varieties used, chiefly Chemlali, being especially adapted to such conditions and affording a high percentage of oil.

The examples presented in this paper are those of the endurance of extremes of drought and neglect by varieties of the olive commonly grown in the south of Europe under conditions of sufficient, if not abundant, moisture. Their growth as trees in these arid situations in Arizona and California, interesting and suggestive as it is, would not warrant their maintenance as a commercial oil-producing enterprise. But the Chemlali and other varieties of the olive are profitably grown for oil production in the north of Africa without irrigation, and under conditions of soil and climate fairly comparable with those endured by the Arizona groves herein described. Whether the Chemlali variety will make the profitable growth in Arizona, California, and other sections of the Southwest that it has in Tunis can only be determined by careful experimentation.

The possibility that large areas of land within the proper temperature limits and having an ideal soil for the olive, yet without the rainfall or irrigation water necessary for ordinary crops, may be utilized for an olive-oil industry makes it worth while to institute experiments of sufficient extent to thoroughly test the matter. Plantings of more than an experimental character are not warranted by the present extent of our information, and the production of pickling olives is not contemplated.

In each of the instances cited where olive trees have remained alive and growing in spite of the failure of water it is necessary to remember that the plantation was established under irrigation. Likewise, in Tunis the truncheons by which the orchards are propagated are carefully watered by a supply carried from wells until sufficiently rooted to maintain themselves, three waterings usually being sufficient during the first summer. In making selections of tracts for olive culture over the drier areas indicated in Texas, Arizona, and California it must be a further condition of success that a small supply of water from some source can be assured to establish the young trees, after which a local rainfall of 7 to 12 or 15 inches annually may be expected to support the plantation and enable it to produce fair yields of fruit—perhaps enough to render dry-land olive culture profitable on a commercial scale.

SUMMARY.

In several localities in southern California and Arizona olive groves have been planted along with apricots, figs, grapes, and some other fruits. The irrigation projects under which these plantings were made subsequently failed, leaving the fruit trees without any water other than the rainfall.

The local rainfall of 3½ to 8 or 10 inches annually has proved insufficient to maintain life in any of these plants except the olive, which has been found in many instances green and flourishing after six or eight years of abandonment and lack of irrigation.

Under these conditions the olive has shown the characteristics of a desert plant, competing with the mesquite, cat's-claw, and greasewood in their own territory. The plantations which have been studied are the Bogart-Degolia grove near Casa Grande, Ariz., a grove near Florence, Ariz., and "Las Palmas" trees in the olive belt northeast of Phoenix, localities having a mean annual rainfall of 7 to 9 inches; and in California, the Pope olive grove near Palm Springs, in the upper end of the Colorado Desert, where, with an annual average rainfall of only 3½ inches, 20 acres of olives have survived six years without irrigation and are still growing.

The soils of the localities are sandy and gravelly clays derived from the disintegration of the soft granitic rocks of the adjacent mountains. They are low in organic matter, but fairly rich in available phosphoric acid and potash. The soil at Palm Springs is a nearly pure granitic sand and gravel, very low in silt, clay, and humus, but showing by analysis percentages of potash and phosphoric acid equal to the better agricultural soils of the Mississippi Valley.

A study of the olive trees growing under these conditions has shown that unlike the mesquite and some other desert trees they do not survive by sending roots down to subterranean supplies of moisture, but develop instead a very elaborate system of roots occupying the soil at from 2 or 3 to 18 inches in depth and adapted to gathering moisture from the lightest rainfall.

The remarkable drought resistance of the olive is made possible (1) by the power these trees possess of extending their roots so as to gather moisture from a large area; (2) by their habit of growth in forming low spreading tops which protect the trunk and main branches from the burning heat of the sun; and (3) by the character of their leaves, which are constructed in a manner calculated to check evaporation and conserve the moisture obtained by the roots.

The plantations studied were made according to irrigation standards and contained originally from 75 to 114 trees to the acre. These plantings have proved too thick for successful growth without irrigation.

The varieties used in these orchards are the ones commonly grown under conditions of sufficient rainfall in France and Italy or with an abundance of irrigation in California.

The publication in 1908 of Bulletin 125 of the Bureau of Plant Industry, entitled "Dry-Land Olive Culture in Northern Africa," by Mr. Thomas H. Kearney, has brought to our attention the existence of a great oil-olive industry many centuries old, in the north of Africa, dependent on an average annual rainfall of 9.3 inches. The principal varieties grown are probably of local origin, adapted to these conditions through years of selection.

Very wide planting allows a great spread of roots for moisture gathering, while a system of clean cultivation and dust-mulch forming in vogue in that country before it was occupied by Europeans conserves to the utmost the meager rainfall.

The most drought resistant of these varieties, the Chemlali, has been imported by the Bureau of Plant Industry, and is being tested at a number of localities in the Southwestern States.

In view of the remarkable drought resistance shown by European olive varieties accustomed to abundant moisture, as shown in this bulletin, it is believed that with the planting of this desert-bred variety from Africa and the adaptation to our conditions of the Tunisian methods of planting and culture, large areas of land in the Southwestern States possessing a suitable soil and climate but now undeveloped from lack of irrigation water are adapted to produce olive oil.

Trial plantations are now being made at various points in this region to determine whether such dry-land olive culture will prove profitable on a commercial scale under American conditions.

APPENDIX.

ANATOMICAL STRUCTURE OF THE OLIVE (OLEA EUROPEA).[a]

By Dr. Theo. Holm.

ROOT STRUCTURE OF THE OLIVE.

Characteristic of the root structure of the genus Olea is the presence of stereome on the inner face of the pericambium and the prevalence of cambial cell divisions on the inner face of the leptome. Otherwise, the arrangement and development of the various tissues is not different from that of many other dicotyledons.

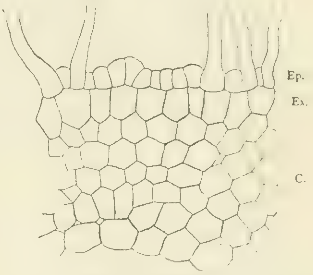

Fig. 11.—Transverse section of a young lateral root of the third order of an olive tree from Palm Springs, Cal., showing a hairy epidermis (Ep.) and cortex (C.).

The structure is as follows: In the young lateral roots of the third order (figs. 11 and 12) the epidermis (Ep.) is very hairy and covers an exodermis (Ex.) of thin-walled cells in a single layer; this exodermis is not contractile. The cortex (C.) is compact and thin walled; it consists of eight layers, more or less filled with starch; a thin-walled endodermis (End.) is plainly visible, bordering on the pericambium (P.) which shows isolated strands of stereome (St.) outside the leptome. The stele is tetrarch, there being four strands of leptome (L.) alternating with four rays of hadrome (H.), which extend to the center of the stele. Increase in thickness begins even in these thin roots, since cambial (Camb.) divisions are noticeable on the inner face of the leptome, although the increase does not extend beyond the formation of these few layers.

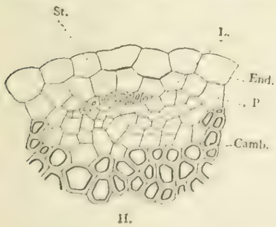

Fig. 12.—Inner portion of the same transverse section of the olive root shown in figure 11. (× 210.)

In lateral roots of the first or second order, on the other hand, the increase in thickness attains much larger dimensions, due to the activity of the pericambium in developing phellogen (Ph.) and cork (Co.) (fig. 13), besides a secondary cortex (C*) (fig. 14), to say nothing of the continued cambial cell divisions on the inner face of the leptome, as observed already in the much thinner lateral roots.

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[a] This description of the anatomy of olive roots, leaves, and stems, with ten illustrations, was prepared at the writer's request by Dr. Theo. Holm, of Brookland, D. C., from material collected from several California groves.

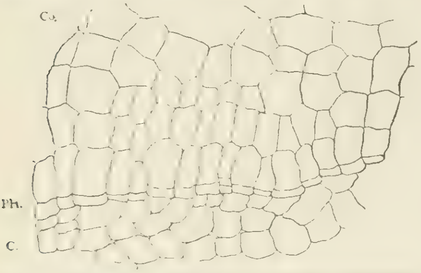


FIG. 13.—Transverse section of a lateral root of the first or second order of an olive tree, showing the development of phellogen (Ph.) and cork (Co.). (× 120.)

The result of these various increases (fig. 14) is the development of a broad zone of cork, the development of a secondary cortex (C*), the development of a closed sheath of pericambial stereome (St.), and finally from the cambial strata the development of secondary leptome and hadrome (L. and H.) with rays of parenchyma (P.).

The diagram (fig. 15) shows the arrangement of all these tissues except the epidermis and the exodermis, which have, of course, been thrown off before this stage is reached. The center of the root possesses remnants of the primitive root stele, from which rays of parenchyma extend toward the secondary cortex (C*). The root of the genus Olea shows the arrangement of the several tissues in a remarkably regular way, and the presence of pericambial stereome is interesting.

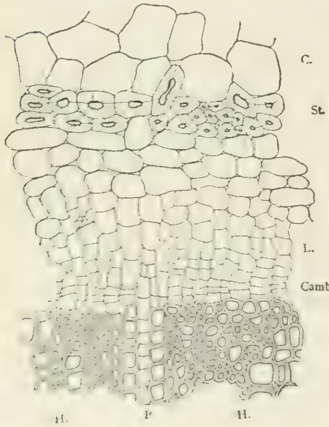


FIG. 14.—The same transverse section shown in figure 13 of the root of an olive tree, showing the development of a secondary cortex (C*) and parenchyma (P.) rays from the cambial (Camb.) strata. (× 120.)

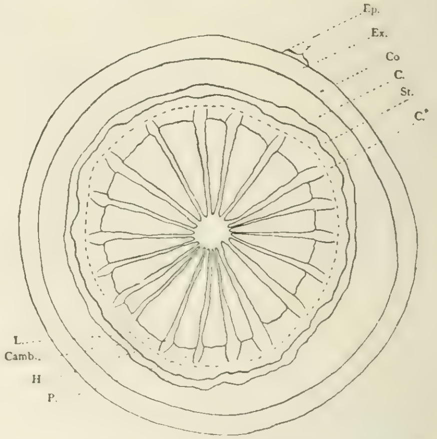


FIG. 15.—Diagram of the root of an olive tree, showing the general arrangement of tissues described in figures 11 to 14, inclusive. (× 22½.)

LEAF AND STEM STRUCTURE OF THE OLIVE.

The structure of the olive leaf is that of a xerophyte; in other words, it shows in a high degree peculiarities of structure that characterize most woody plants that grow in situations where both air and soil normally contain a relatively small amount of moisture. On the upper surface of the leaf the cuticle and outer walls of the epidermis cells are greatly thickened, stomata are absent, and shield-shaped hairs are scattered over the surface. On the lower face the outer walls of the epidermis cells are very thick (though less so than on the upper surface), the stomata are placed at the bottom of narrow pits, and shield-shaped hairs form a dense continuous covering. The interior, chlorophyll-bearing tissue (chlorenchyma) consists of three or four very compact layers of palisade cells (i. e., narrow cells, elongated at right angles to the epidermis) beneath the upper epidermis, and between the palisades and the lower epidermis many layers of so-called pneumatic tissue, the cells of which are very irregular in shape, not much longer than wide, and inclose numerous air spaces. Prosenchymatic cells with very thick walls (the stereome), either singly or in groups, are scattered through the mesophyll and occur here and there directly beneath the epidermis, as well as in several continuous layers adjoining the midrib. Between the midrib and the sheath of stereome there is no chlorenchyma, but extending to the epidermis on both sides are several layers of collenchyma, of which the cells contain no chlorophyll and have their walls greatly thickened, especially at the angles.

Of the foregoing characters, those which may be pointed out as especially xerophytic are: Thickness of the cuticle and outer cell walls of the epidermis, absence of stomata on the upper surface and their situation in pits on the lower face, and the dense covering of flat, shield-shaped hairs on the lower face. These characters are supposed to be especially useful to plants that inhabit dry climates or that grow in soils from which their roots obtain moisture with difficulty, by protecting the leaves from excessive loss of water through transpiration. The development of the chlorenchyma beneath the upper face of the leaf into several layers of compact palisade tissue is also characteristic of many xerophytes.

In leaves of the olive developed in the shade or in a moist atmosphere, the cell walls of the epidermis are much thinner, the stomata are level with the surface instead of being situated in pits, and the midrib is embedded in chlorenchyma, with a much smaller development of collenchyma.

Leaves and young twigs of olive trees were collected in abandoned orchards at Phoenix, Ariz., and at Palm Springs, Cal. In the former case the tree had been without irrigation for six years and in the latter case seven years. Since in both cases the ground water was out of reach of the roots and since the average yearly rainfall in Phoenix is but 8.11 inches and at Palm Springs only 3.5 inches, it is evident that these leaves were produced under extremely arid conditions. In fact, the conditions at Palm Springs probably represent the extreme of drought that the olive tree can endure. In both cases the varieties were not identified. For purposes of comparison, similar material of the Mission olive, the variety most widely grown in California, was obtained at Niles, Cal., where the trees are irrigated at least once during the season and where the average yearly rainfall is 14.8 inches, with a low evaporation due to the cool summer climate. The leaf and stem structure of the last, which may be regarded as typical of *Olea europea* in the western United States, is as follows:

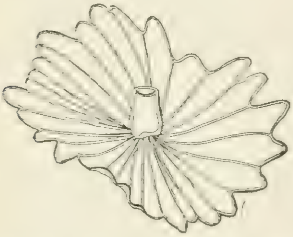


FIG. 16.—One of the peltate hairs from the surface of an olive leaf. (× 150.)

On the upper (ventral) face the cuticle is smooth and thick; the lateral walls of the epidermis cells, viewed superficially, are straight and very much thickened; stomata are wanting and peltate hairs (fig. 16) are scattered over the surface. On the lower (dorsal) face the cuticle is similar; the radial walls of the epidermis cells are almost straight, but not so much thickened as on the upper face; the numerous stomata (fig. 17) are sunken, with narrow and not very deep air chambers, and are surrounded by a variable number of undifferentiated epidermis cells; peltate hairs (fig. 16) are abundant, forming a continuous covering over the blade. The outer walls of the epidermis cells (figs. 17 and 18) are very thick on both faces of the leaf and show an increase in thickening very plainly. On the dorsal face they show many deepenings caused by the irregular thickening of the cell wall (fig. 17). The inner and radial cell walls of the epidermis are rather thin as compared with the outer walls. The unicellular stalks of the large shield-shaped hairs are located in circular cavities, the peltate part of the hair, which consists of numerous radially arranged cells, resting upon the outer wall of the epidermis.

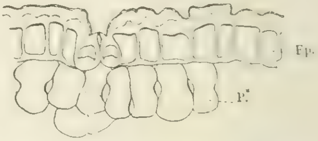


FIG. 17.—A sunken stoma and the uneven dorsal surface of an olive leaf.

The chlorenchyma is differentiated into palisade and pneumatic tissues. The former (fig. 18) consists of three compact layers of very high cells containing chlorophyll and small needle-shaped crystals of calcium oxalate. It extends from the margins of the blade to the midrib, where it ceases, being broken by the hypodermal collenchyma. On the dorsal side of the blade there is a thick pneumatic tissue of many layers. The cells which, like those of the palisade, contain numerous needle-shaped crystals of calcium oxalate, are of a very irregular shape and the intercellular spaces are very wide (fig. 19). The pneumatic tissue, like the palisade tissue, is broken at the midrib by hypodermal collenchyma.

The stereome is thick walled and very unequally distributed. It occurs hypodermally (immediately beneath the epidermis) as single cells or a few cells together on both faces of the blade (fig. 18), as scattered cells in the collenchyma (Pl. V, fig. 1), and as a pericycle of several continuous layers in the midrib (Pl. V, fig. 1). It is characteristic of the genus Olea that the stereome cells traverse the pneumatic tissue in all directions (fig. 19). The pericylic stereome is thick walled only on the hadrome side of the midrib; on the leptome side it is thin walled with a very few thick-walled cells interspersed. The collenchyma (Pl. V, fig. 1) is hypodermal above and below the midrib and extends to the pericycle; it is generally thick walled, especially near the epidermis.

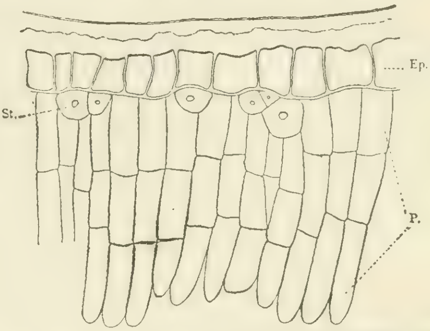


FIG. 18.—Ventral face of an olive leaf, showing the thickened walls of epidermal cells and palisade cells. (× 150.)

The mestome strands are, with the exception of the midrib (Pl. V, fig. 1), embedded in the chlorenchyma, and all the lateral strands are surrounded by thin-walled parenchyma sheaths, sometimes with a few adjoining stereome cells. The midrib has no parenchyma sheath and no endodermis, but, as previously described, it is surrounded by a thick sheath of stereome. All the mestome strands are collateral. The leptome forms an arch underneath the shorter but broader arch of hadrome. In the latter, each double row of vessels is separated from the next by a single row of parenchyma cells (parenchymatic ray).

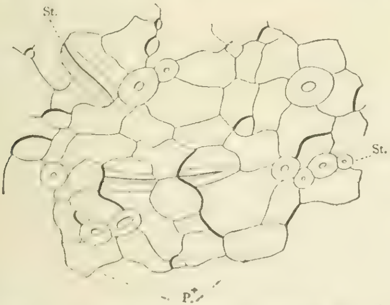


FIG. 19.—Pneumatic tissue of the dorsal side of a blade traversed by stereome cells. From a leaf of the Mission olive. (× 150.)

The petiole, examined at the characteristic point (where the mestome strands enter the leaf blade), shows a hemicylindric outline in cross section. It is covered with shield-shaped hairs, as is the blade, and the outer walls of the epidermis cells are extremely thick. The cortex is a solid mass of collenchymatic tissue and contains an arch-shaped collateral mestome strand in the center. This mestome strand has no support of stereome in the stricter sense of the word, but is simply surrounded by a small collenchymatic tissue. Leptome and hadrome show the same structure as in the midrib of the blade.

The arrangement of the tissues of the stem is shown in Plate V, figure 2. The cross section of the young twig is quadrangular and minutely four winged. The thin, smooth cuticle covers an epidermis with hairs similar to those of the leaf, and the outer cell walls are very thick; inside the epidermis are about twelve layers of cortical parenchyma, collenchymatic in the peripheral layers but more thin walled around the stele. Phellogen appears in the outermost layer of the cortex and soon develops several layers of cork, of which about three develop during the first summer. (Fig. 20.)

There is no endodermis, but a stereomatic and very thick-walled pericycle surrounds the stele. This pericycle, however, is not continuous, but consists of many strands of stereome separated by a few parenchymatic cells. The leptome presents a circular zone bordering on the pericycle, and is separated by cambium from the hadrome. The vessels (the scalariform ones especially) are thick walled and separated from each other by parenchymatic rays, each of a single row of rather thin-walled cells. The cells of the pith (which is solid) have thick porous walls and contain much starch.

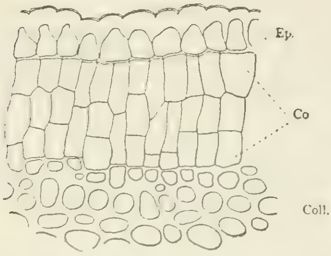


FIG. 20.—Development of cork layers in the cortex of an olive stem. (× 150.)

As compared with the preceding (the Mission variety from Niles, Cal.), the unknown variety of olive of which material was collected in the orchard at Phoenix, Ariz., is noteworthy for the extremely thick-walled epidermis on both faces of the leaf; thick-walled collenchyma extending from the epidermis to the pericycle of the midrib; more stereome in the pericycle; palisade and pneumatic tissues more compact but containing less stereome. In the petiole all the tissues are extremely thick walled. Cork develops very early in the stem, since even in the apical internode there are seven layers. The epidermis of the apical internode is extremely thick walled.

The two unidentified varieties collected in the abandoned orchard at Palm Springs appear to be identical in anatomical structure. From the variety growing at Phoenix they differ only in the much narrower midrib.

To summarize: The leaf and stem structure of the olive are such as to protect it admirably against excessive loss of water by transpiration and hence adapt it to growing in very dry soils and climates. The scanty evidence here presented would seem to indicate that the considerable difference in aridity represented by the two environments at Niles (where the average yearly rainfall is 14.8 inches, where moisture-laden winds blow in from the ocean, and where occasional irrigation is given) and of Palm Springs (where the average yearly rainfall is only 3.5 inches, where the air is excessively dry, and where the trees had received no irrigation for seven years) has a distinct, though comparatively slight, effect upon the anatomical structure of this plant, for even at Niles the olive exhibits in a high degree the characteristics of a xerophytic plant.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Fig. 1.—One of the larger olive trees on the Bogart-Degolia plantation near Casa Grande, Ariz. Fig. 2.—Olive trees in the "Las Palmas" section, near Phoenix, Ariz., after six years of neglect and lack of water.

Plate II. Fig. 1.—View in the Florence, Ariz., olive grove, about 16 years old, which has had no irrigation for the past six years. At the left, dead apricot and almond trees of the same age; at the right, olive trees in vigorous condition. Fig. 2.—Interior view in the grove shown in figure 1, showing a fine growth but thinner foliage than in the outer row shown in figure 1, due to the crowding of the trees.

Plate III. Fig. 1.—View in the Pope olive plantation, near Palm Springs, Cal., after six years of neglect. Mean annual rainfall only 3½ inches. Fig. 2.—One of the larger trees, 8 feet high, in the Pope olive plantation, showing the low habit of growth and the protection of the trunk and main branches from heat by a canopy of foliage.

Plate IV. Fig. 1.—Characteristic burl at the base of an olive tree on the Pope olive plantation, near Palm Springs, Cal. Fig. 2.—Feeding rootlets, natural size, from 6 inches in depth, on the same plantation shown in figure 1.

Plate V. Fig. 1.—Cross section of the midrib of the leaf of Olea europea (Mission variety), showing the epidermis, palisade tissue, massively developed collenchyma, pericyclic stereome, hadrome, leptome, and pneumatic tissue. Magnified 180 times. Fig. 2.—Cross section of one of the apical internodes of the stem, showing the epidermis, hypodermal collenchyma, stereome ring, leptome, hadrome, and pith. Magnified 112 times.

Plate VI. Fig. 1.—View in a 500-acre olive plantation in southern Los Angeles County, near La Mirada, Cal., grown without irrigation. The planting distance of 20 feet each way is much too close for the full development of the trees. Fig. 2.—View in a different part of the plantation shown in figure 1, where the trees have been thinned by removing alternate diagonal rows. The conditions are consequently much improved.

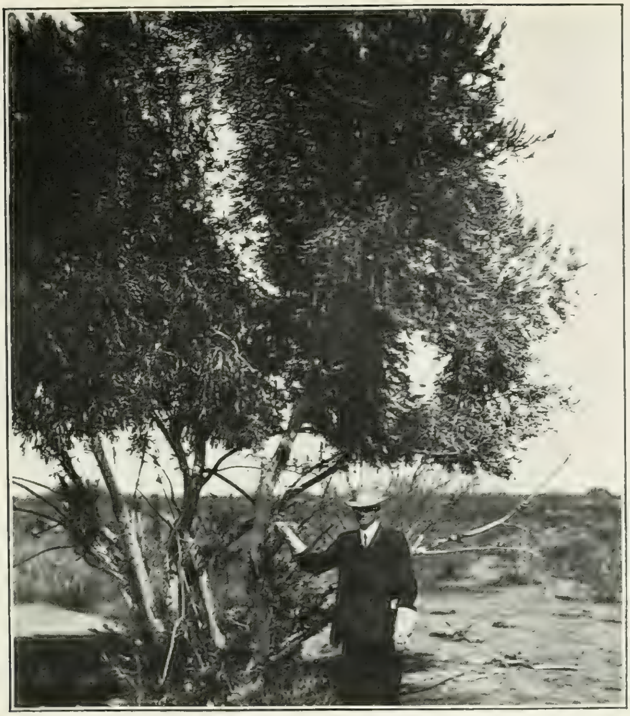


FIG. 1.—ONE OF THE LARGER OLIVE TREES ON THE BOGART-DEGOLIA PLANTATION, NEAR CASA GRANDE, ARIZ.

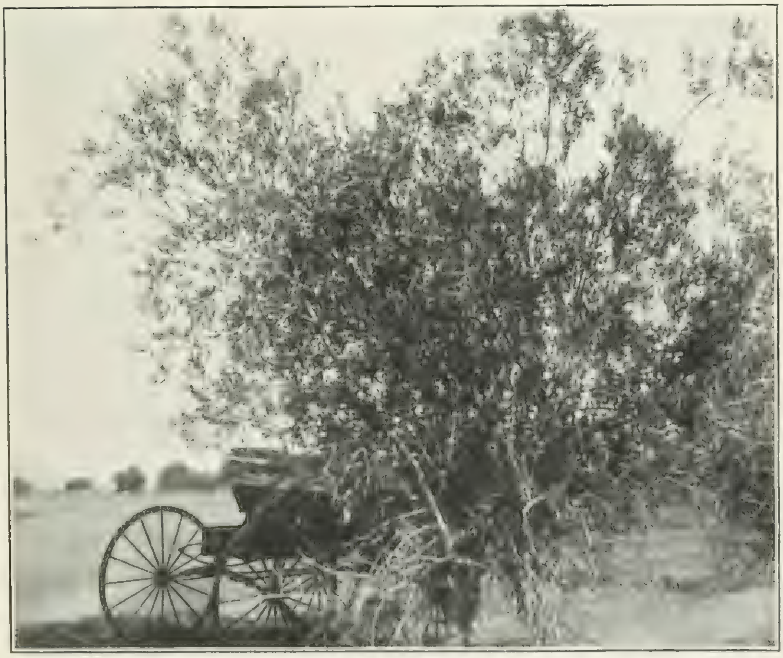


FIG. 2.—OLIVE TREE AT "LAS PALMAS," NEAR PHOENIX, ARIZ., AFTER SIX YEARS OF NEGLECT.

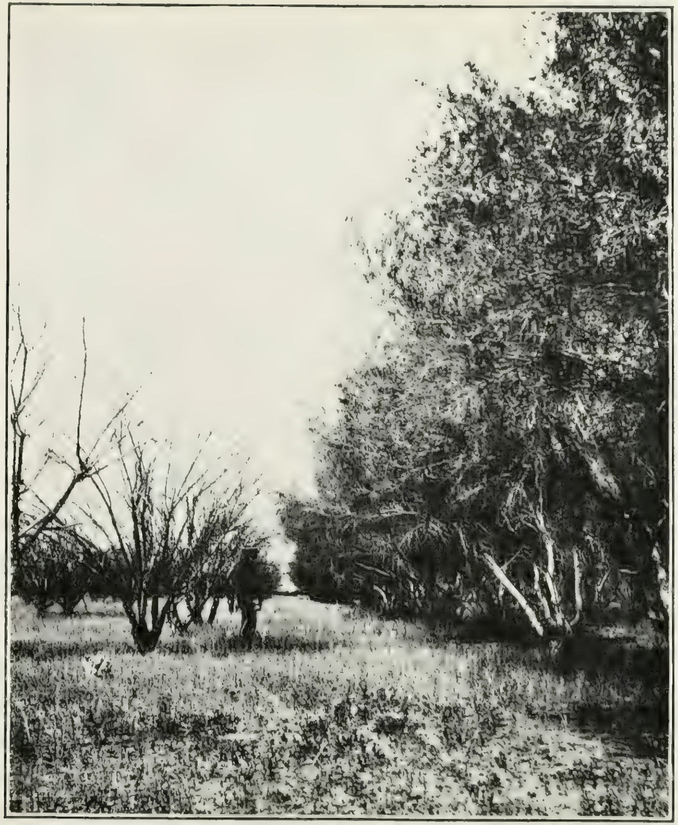


FIG. 1.—VIEW IN THE OLIVE GROVE AT FLORENCE, ARIZ., SHOWING DEAD APRICOT AND ALMOND TREES IN CONTRAST WITH FLOURISHING OLIVES AFTER SIX YEARS WITHOUT IRRIGATION.

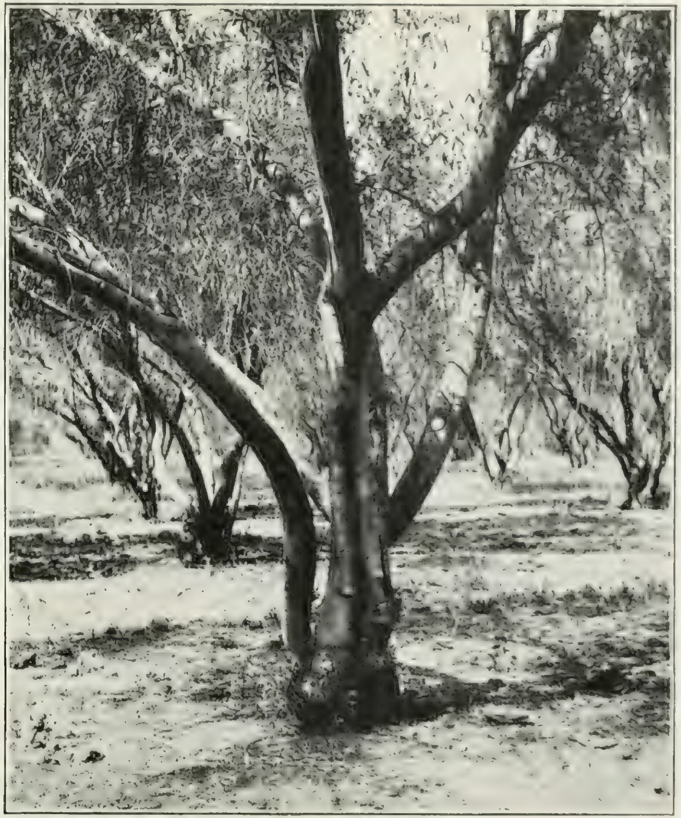


FIG. 2.—INTERIOR VIEW IN THE GROVE SHOWN IN FIGURE 1, THE FOLIAGE, ON ACCOUNT OF CROWDING, HAVING BECOME THINNER THAN THAT OF THE OUTER ROW.

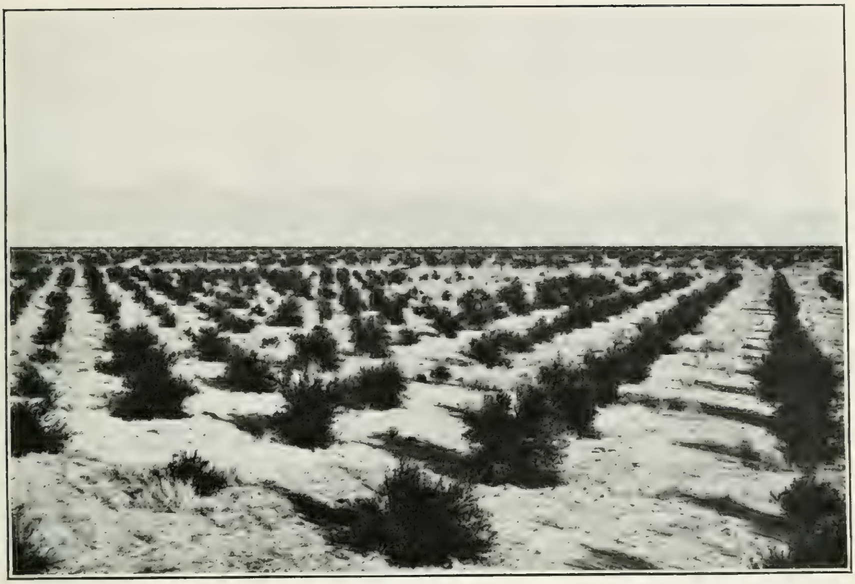


FIG. 1.—VIEW IN THE POPE OLIVE PLANTATION, NEAR PALM SPRINGS, CAL., AFTER SIX YEARS OF NEGLECT.

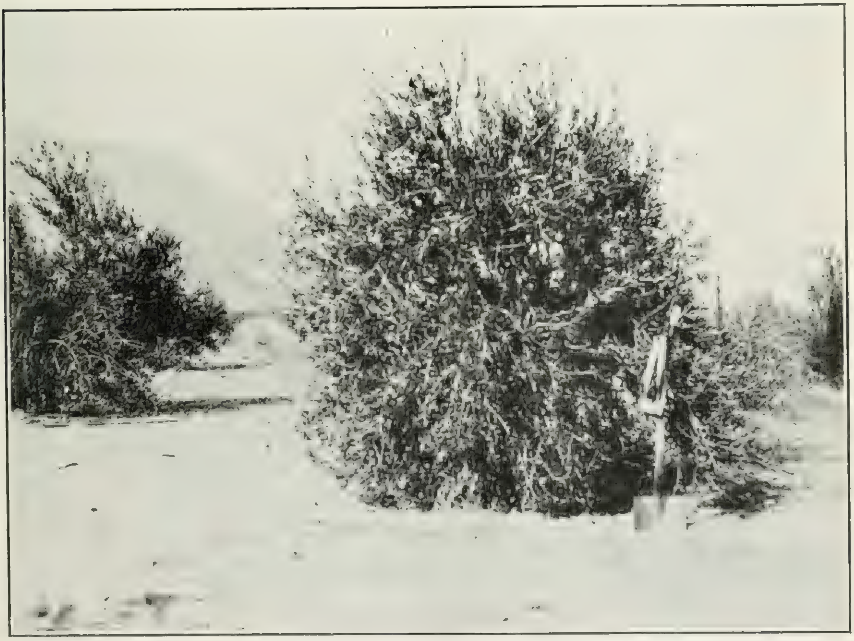


FIG. 2.—ONE OF THE LARGER TREES IN THE POPE OLIVE PLANTATION, SHOWING THE LOW HABIT OF GROWTH OF THE TREES.

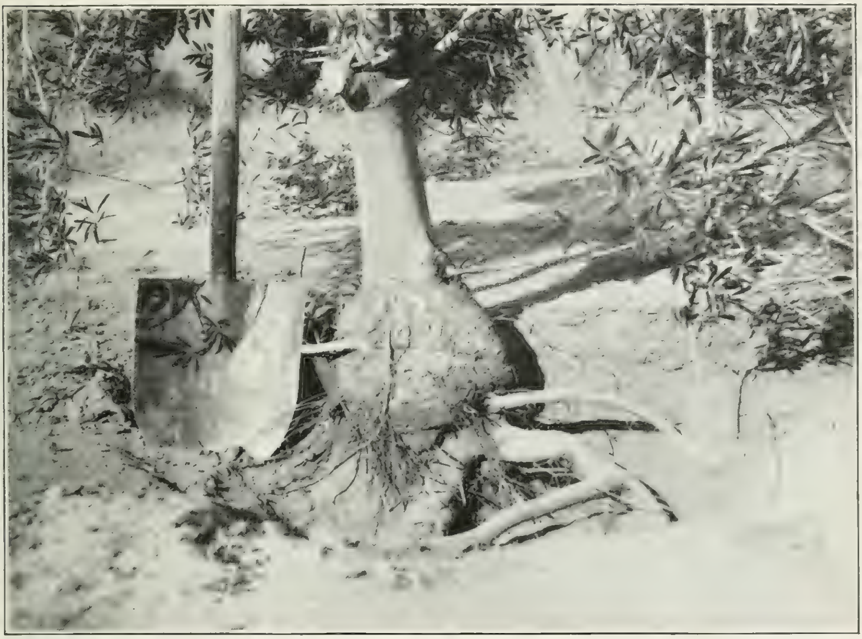


FIG. 1.—CHARACTERISTIC BURL AT THE BASE OF AN OLIVE TREE ON THE POPE PLANTATION, NEAR PALM SPRINGS, CAL.

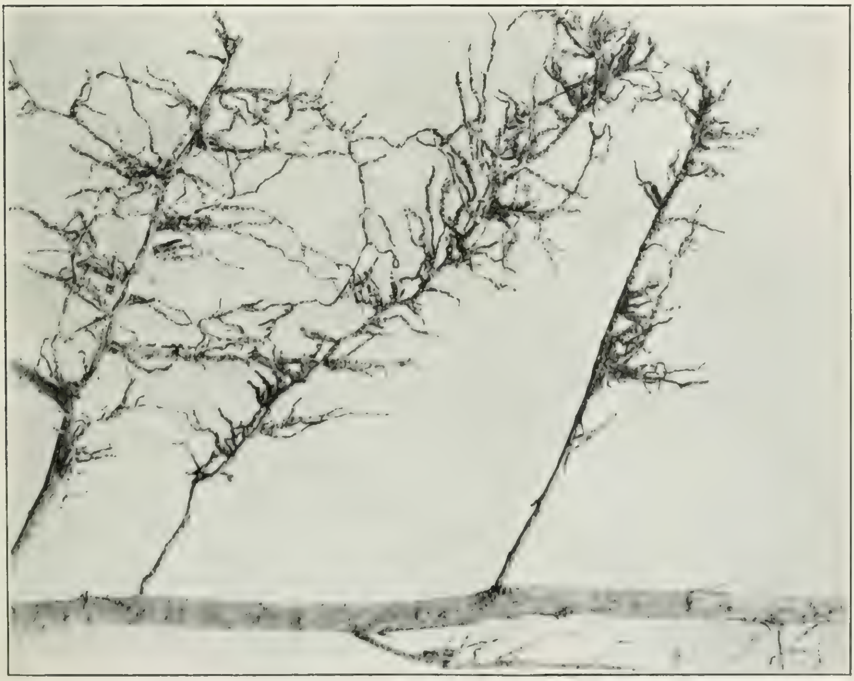
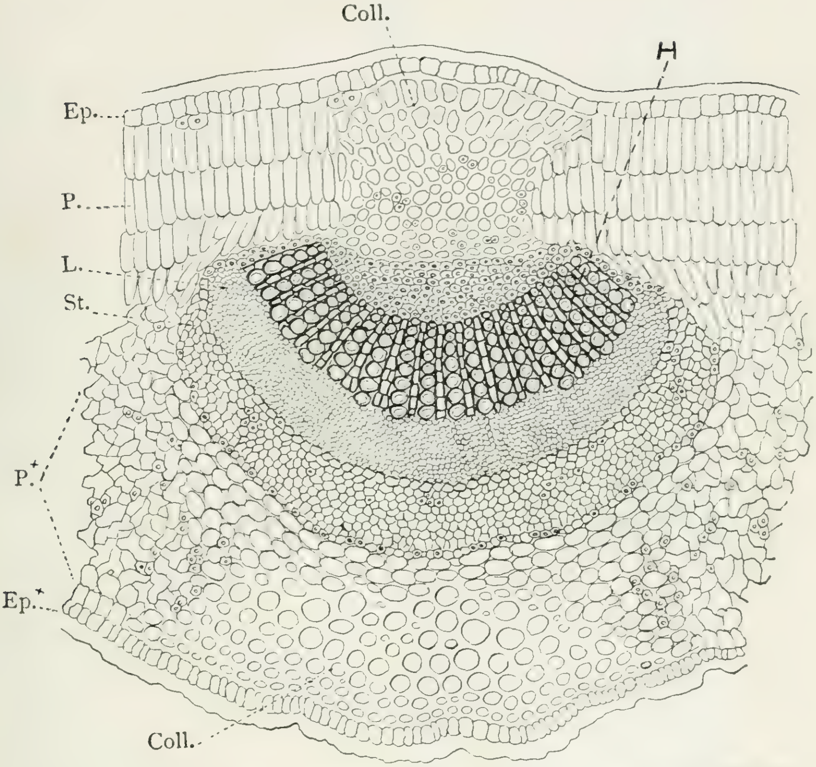


FIG. 2.—FEEDING ROOTLETS, FROM 6 INCHES IN DEPTH, ON THE POPE OLIVE PLANTATION. (NATURAL SIZE.)


Coll.
H
Ep.
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L.
St.
P.+
Ep.+
Coll.

FIG. 1.—CROSS SECTION OF THE MIDRIB OF THE LEAF OF OLEA EUROPEA (MISSION VARIETY).

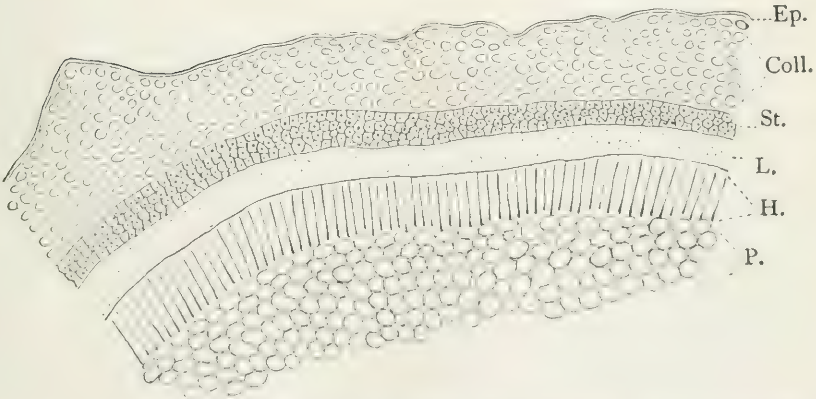
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FIG. 2.—CROSS SECTION OF ONE OF THE APICAL INTERNODES OF THE STEM OF OLEA EUROPEA (MISSION VARIETY).

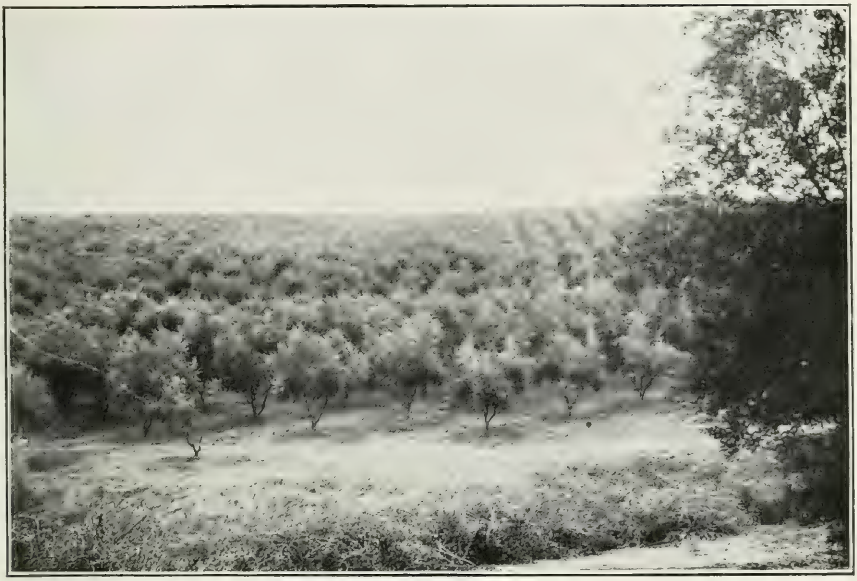

FIG. 1.—VIEW IN THE 500-ACRE OLIVE PLANTATION NEAR LA MIRADA, CAL.

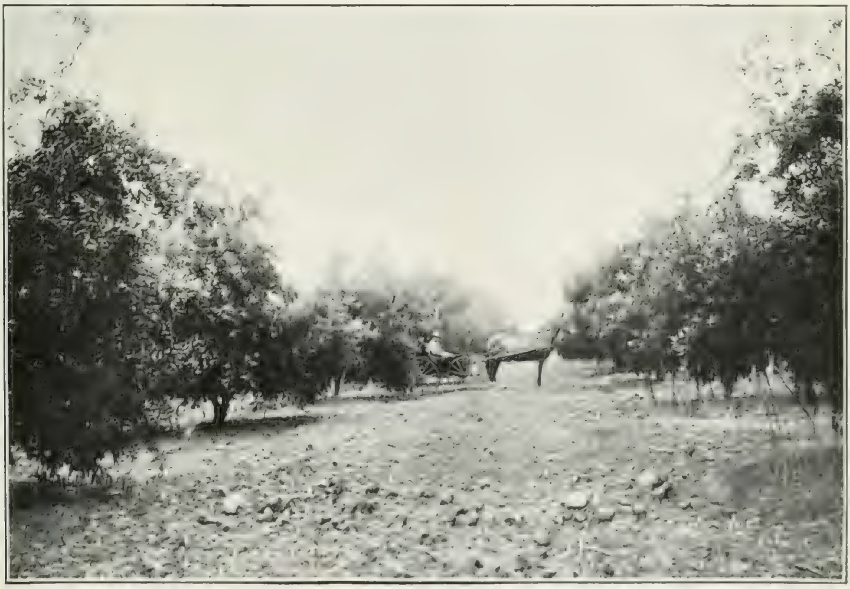

FIG. 2.—VIEW IN A DIFFERENT PART OF THE PLANTATION SHOWN IN FIGURE 1, WHE E THE TREES HAVE BEEN THINNED BY REMOVING ALTERNATE DIAGONAL ROWS.

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Reprint February 18, 1911.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 193.

B. T. GALLOWAY, *Chief of Bureau.*

EXPERIMENTS IN BLUEBERRY CULTURE.

BY

FREDERICK V. COVILLE,

BOTANIST IN CHARGE OF TAXONOMIC AND RANGE INVESTIGATIONS.

ISSUED NOVEMBER 15, 1910.

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Taxonomic and Range Investigations.

SCIENTIFIC STAFF.

Frederick V. Coville, *Botanist in Charge.*
A. S. Hitchcock, *Systematic Agrostologist.*
W. F. Wight, *Botanist.*
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W. E. Safford, *Assistant Curator.*
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 19, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 193 of the series of this Bureau a manuscript by Mr. Frederick V. Coville, Botanist in Charge of Taxonomic and Range Investigations, entitled "Experiments in Blueberry Culture." Mr. Coville has found by experiment how blueberries differ from ordinary plants in their method of nutrition and in their soil requirements, and by means of this knowledge he has worked out a system of pot culture under which these plants attain a development beyond all previous expectations. There is good prospect that the application of the knowledge thus gained will establish the blueberry in field culture and that ultimately improved varieties of these plants will be grown successfully on a commercial scale.

A particularly interesting and significant feature of these experiments is the light they shed on the possible utilization of the naturally acid lands that occupy extensive areas in the eastern United States. These lands are generally valued at a low price, and the chief expense involved in their utilization for ordinary agricultural crops is the cost of correcting their acidity and its effects by liming, fertilizing, and cultural manipulation. The question presents itself, "May we not more effectively utilize such lands by growing on them crops which, like the blueberry, thrive in acid soils?"

Some of the experimental methods and equipment utilized by Mr. Coville are commended to other plant experimenters, especially the use of darkened and drained glass pots for the intimate observation of the behavior of roots, and the plunging of pots in moist sand to maintain equable moisture and aeration conditions.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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(5) The swamp blueberry does not thrive in a thoroughly decomposed leaf mold, such as has a neutral reaction 24

(6) The swamp blueberry does not thrive in soils having a neutral or alkaline reaction, but for vigorous growth it requires an acid soil 26

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(8) Peat suitable for the swamp blueberry may be found either in bogs or on the surface of the ground in sandy oak or pine woods. 32

(9) For active growth the swamp blueberry requires a well-aerated soil. Conversely, the swamp blueberry does not continue in active growth in a soil saturated with water 35

(10) Aeration conditions satisfactory for the swamp blueberry are prevalent in sandy soils 36

(11) Aeration conditions satisfactory for the swamp blueberry are found in drained fibrous peat 37

(12) Aeration conditions satisfactory for the swamp blueberry are found in masses of live, moist, but not submerged, sphagnum.. 38

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(13) The swamp blueberry is devoid of root hairs, the minute organs through which the ordinary plants of agriculture absorb their moisture and food 40

(14) The rootlets of healthy plants of the swamp blueberry are inhabited by a fungus, of the sort known technically as an endotrophic mycorrhiza 42

(15) The mycorrhizal fungus of the swamp blueberry appears to have no injurious effect, but rather a beneficial effect, upon the blueberry plant 44

(16) The acid peaty soils in which the swamp blueberry thrives are deficient in "available" nitrogen, although containing large amounts of "nonavailable" nitrogen 45

(17) The deficiency of available nitrogen in the acid peaty soil in which the swamp blueberry grows best is due to the inability of the nitrifying bacteria to thrive in such a soil because of its acidity 46

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Peculiarities of nutrition—Continued.

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(18) From the evidence at hand the presumption is that the mycorrhizal fungus of the swamp blueberry transforms the nonavailable nitrogen of peaty soils into a form of nitrogen available for the nourishment of the blueberry plant 48
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(32) Plants of the swamp blueberry are exceedingly hardy and pass the winter in good condition outdoors when the soil is covered merely with an oak-leaf mulch, but when not exposed to outdoor conditions they do not begin their growth in spring in a normal manner 74
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(34) Unless pollinated by an outside agency, such as insects, the flowers produce little or no fruit 76
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EXPERIMENTS IN BLUEBERRY CULTURE.

INTRODUCTION.

In the grounds of the Smithsonian Institution at Washington are two blueberry bushes of large size and great age. The taller is about 9 feet high. The largest stem is nearly 3 inches in diameter. It is known that these bushes were growing prior to 1871, thirty-nine years ago, and all the evidence indicates that they were planted at a much earlier date. They are probably over 50 years old.[a] In the Arnold Arboretum, near Boston, are many blueberry bushes 30 years old or more, grown from the seed by Mr. Jackson Dawson or transplanted from their wild habitats prior to 1880.

The two cases here cited demonstrate the fallacy of the popular idea that the blueberry can not be transplanted or cultivated. This idea rests on the unsuccessful experience of those who have taken up wild bushes and set them in a rich, well-manured garden soil. These are exactly the conditions, as shown by experiments described in this publication, under which blueberry plants become feeble and unproductive.

Four agricultural experiment stations, those of Maine, Rhode Island, New York, and Michigan, have attempted to grow the blueberry as a fruit, but none of these attempts has resulted in the commercial success of blueberry culture, and the experimental results have been chiefly of a negative character. This outcome appears to have been due to a misunderstanding of the soil requirements of the blueberry, which, as will be shown later, are radically different from those of our common cultivated plants.

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[a] The plants are *Vaccinium atrococcum*, a species closely related to *Vaccinium corymbosum*, the well-known swamp or high bush blueberry of the Northern States. In a list of the trees and shrubs of the Smithsonian grounds prepared by Arthur Schott in 1871, these bushes are included, but identified, however, as *Vaccinium fuscatum*. The late Mr. George H. Brown, for more than a generation the superintendent of planting in the parks of Washington, also assured the writer that these plants were not set out since he first became responsible for the Smithsonian grounds, in 1871. The present plan of the grounds was made by Mr. Andrew J. Downing, but the actual planting was not done until after his death, in 1852. It is possible that the blueberry bushes may have been set out as early as 1848, in which year a partial planting of the Smithsonian grounds was made by Mr. John Douglass.

In the Boston market there is a wide variation in the wholesale price of blueberries. Shipments begin in early June from North Carolina, followed in the latter part of the month by blueberries from Pennsylvania, New Jersey, and New York. In early July, or in some years in the last days of June, Massachusetts and New Hampshire shipments begin to arrive, succeeded in late July or early August by berries from Maine, Nova Scotia, and New Brunswick. Receipts from these last two localities continue until late September. The blueberries that bring the highest price are those from Massachusetts and New Hampshire. At the time when other berries are selling at 8 to 15 cents per quart wholesale, the first shipments of New Hampshire berries often bring 20 to 23 cents.

The owner of a blueberry pasture in southern New Hampshire who superintended the picking of his own berries and shipped them to one of the secondary New England cities has courteously shown his shipment records, from which the following data have been compiled:

Records of shipments from a blueberry pasture in southern New Hampshire, 1905–1909.

Year.	Date of shipment.	Total shipments.	Highest and lowest price per quart.[a]	Average price per quart.[a]
		Quarts.	*Cents.*	*Cents.*
1905	July 1 to Aug. 14	2,233	12½ to 8	10.7
1906	July 17 to Aug. 15	2,756	15 to 8	9.6
1907	July 20 to Aug. 15	2,538	14⅓ to 11	12.2
1908	June 29 to Aug. 15	3,602	16 to 9½	10.8
1909	July 15 to Aug. 16	1,255	14 to 9	10.7

[a] This is the net price that the shipper received after deducting express charges.

The average net price for the five years was 10.8 cents per quart. The record indicates the substantial returns that are secured from ordinary wild berries picked and sent to market in rather better than ordinary condition.

That the market would gladly pay a high price for a cultivated blueberry of superior quality there can be no doubt. From the market standpoint the features of superiority in a blueberry are large size; light-blue color, due to the presence of a dense bloom over the dark-purple or almost black skin; "dryness," or freedom from superficial moisture, especially the fermenting juice of broken berries; and plumpness, that is, freedom from the withered or wrinkled appearance that the berries begin to acquire several days after picking. While the connoisseur in blueberries who picks his own fruit knows the widely varying flavors in the berries of different bushes, the buyer in the city market is content to select his fruit according to its appearance, knowing that the flavor will be good enough in any event.

The size of the seed gives the buyer in New England markets very little concern, for there the name blueberry is restricted to plants of the genus Vaccinium, all of which have seeds so small as to be unnoticeable when the berry is eaten, while the name huckleberry is applied with nearly the same precision to the species of the genus Gaylussacia, in which the seed is surrounded by a bony covering like a minute peach pit, which crackles between the teeth. In southern cities the fruits of both Vaccinium and Gaylussacia are called huckleberries, and it is probable that the low estimation in which the fruit of Vaccinium is there held is largely due to the lack of a distinctive popular name. To distinguish the two berries by their appearance is difficult for any but an expert, for while huckleberries are mostly black and blueberries mostly blue, some of the blueberries, or species of Vaccinium, are black, and some of the huckleberries are blue, notably *Gaylussacia frondosa*, a species often abundant in the sandy soils of the Atlantic Coastal Plain, which has a large, handsome berry of a beautiful light-blue color and passable flavor, but with the disagreeably crackling seed pits characteristic of the other true huckleberries.

The blueberry withstands the rough treatment incident to shipment so much better than most other berries that with proper handling it should always reach the market in first-class condition. But its good shipping qualities are often abused, and the fruit not infrequently is exposed for sale partly crushed and the berries covered with soured juice and made further offensive by the presence of flies. This is the prevailing condition of blueberries and huckleberries in the markets of Washington, in striking contrast with the dry, plump berries of the Boston market. This bad condition is due usually to improper picking.

The small size of the blueberry, compared with other berries, renders the picking of it expensive. The owners of blueberry pastures commonly pay two-thirds the net price of the berries to their pickers. In order to reduce the cost of picking, various devices have been employed. The most widely used of these is an implement known as a blueberry rake, a scoop shaped somewhat like a deep dustpan, provided in front with a series of long, pointed fingers of heavy wire. With this implement an ordinary picker in the blueberry canning districts of Maine, for example, gathers 3 to 5 bushels a day, for which he receives $1\frac{3}{4}$ to 2 cents per quart. Blueberries can be picked with a rake at about a fourth the cost of picking by hand. For this reason many of the berries that go to market are picked with a rake, and it is these berries which, broken and fermenting, make up the greater part of the low-grade stock so offensive to the eye and the taste. Blueberries intended for the market should never be picked with a rake.

What has been said regarding the high cost of picking ordinary blueberries by hand indicates the importance of securing a berry of large size if the plant is to be cultivated. Large size and abundance mean a great reduction in the cost of picking. Large size means also a higher market price, and when taken in connection with good color and good market condition it means a much higher price.

The writer's interest was attracted to the subject of blueberry culture in 1906. In the autumn of that year some experiments were made for him by Mr. George W. Oliver to ascertain a suitable method of germinating the seeds. In the autumn of 1907 special cultural experiments were taken up. In 1908 experiments were begun in the propagation of bushes bearing berries of large size, the most satisfactory of these being a New Hampshire bush of the swamp blueberry (*Vaccinium corymbosum*) having berries a little more than half an inch in diameter. The largest berries tried, a little more than five-eighths of an inch in diameter, were from Oregon bushes of *Vaccinium membranaceum.* Except where otherwise stated, the experiments described in this paper were made with *Vaccinium corymbosum.* The principal results of the experiments are given under brief numbered statements, each followed by a detailed explanation.

PECULIARITIES OF GROWTH IN THE BLUEBERRY PLANT.

SOIL REQUIREMENTS.

(1) THE SWAMP BLUEBERRY DOES NOT THRIVE IN A RICH GARDEN SOIL OF THE ORDINARY TYPE.

Although the statement just made might well rest on the direct observation of experimenters who have failed to make blueberries grow luxuriantly, or sometimes even remain alive, in rich garden soils, nevertheless the citation of one of the writer's experiments may serve to accentuate the fact. The soil chosen for the purpose was the one used at the United States Department of Agriculture for growing roses. A sample of this soil, as mixed by the rose gardener, consisted, according to his specifications, of "five shovelfuls of loam, one shovelful of cow manure, and a handful of lime." The loam used was a rotted grass turf grown on a rather clayey soil. The cow manure was well rotted, having lain in the pile for several months, with almost no admixture of straw. The lime was of the ordinary air-slaked sort.

The pots used in the experiment were of glass, small 5-ounce drinking glasses, about 2 inches in diameter at the bottom, 2½ at the top, and 2¼ inches deep. A small hole bored through the bottom gave the necessary drainage to the soil in the pot. Since the walls of these pots were transparent, the normal growth of the roots and the prevention of an obscuring green growth of microscopic algæ required some arrangement for keeping the light away. This was accomplished either by sinking, or, as gardeners say, " plunging," the pots nearly to the rim in sand, moss, or soil, or, when the pots were not plunged, by fitting closely to the outside of each a removable cuff, as it were, made of the opaque gray blotting paper used in pressing specimens of plants. The use of a pot with transparent walls was found to be of very great importance in the study of these plants, for plants identical in appearance so far as the parts above ground were concerned sometimes showed the most pronounced differences in the growth and behavior of the roots, differences which otherwise would not have been observed but which were in reality responsible for the conspicuous changes that later took place in the growth of the stems and leaves. The use of such glass pots, drained and darkened, is strongly recommended to plant experimenters who use pot cultures, as they afford a means of acquiring easily an intimate knowledge of the great variations in the behavior of the feeding organs, the roots, under different conditions.

On December 22, 1908, six glass pots were filled with the garden soil described above, and a seedling blueberry about an inch in height was transplanted into each. The seed bed from which the seedlings were taken had been allowed to become partially dry before the transplanting was done. In this condition there was no difficulty in removing all of the sandy soil adhering to the roots of a seedling, so that after it was transplanted it must derive its soil nourishment from the new soil exclusively. In potting, the roots of the plant were laid against the glass on one side of the pot so that their behavior could be observed from the very first.

A transplanting of six other plants was then made, similar in all respects to the first except that the soil used was a peat mixture known from earlier experiments to be productive of vigorous growth in blueberry plants. The exact character of this soil will be discussed later in this publication.

This peaty blueberry soil is ill suited to the growth of ordinary plants, while in the garden soil ordinary plants flourish luxuriantly. In order to bring out this fact clearly by an experiment six glass pots containing this garden soil were planted with five alfalfa seeds each, and six more with one rooted rose cutting each. An identical planting was made in twelve pots of blueberry soil.

Average examples of the growth that took place in these plantings are shown in figures 1 to 6, reproduced from drawings carefully made from actual photographs. In the garden soil the rooted rose cutting, which was of the variety known as Cardinal, made vigorous growth of both root and stem, and in forty-four days, when the photograph was taken, had about quadrupled its leaf surface. In the blueberry soil the cutting was barely alive, the roots it had at the time it was potted were nearly all dead, no new stem growth had been made, and the leaflets it bore were only those still persisting from the parent plant.

The alfalfa seeds began to germinate in both soils in three days. At the end of a week a distinct difference in the color of the plants was discernible. In the blueberry soil the seed leaves were darker green in color, the midrib, which shows on the back of the leaf, was purple, the stem was purple, and in some of the seed leaves the whole under surface was purple. In the garden soil the seed leaves were lighter green in color, and in only a few were the stems, and in still fewer the midribs, somewhat purplish. At the end of forty-four days, when the photographs reproduced in figures 3 and 4 were taken, the alfalfa plants in the garden soil were 3 inches in height and vigorous, while the soil was crowded with roots on which nitrogen tubercles had already begun to develop. In the blueberry soil the plants were small leaved and sickly, about a third the height of the others, and

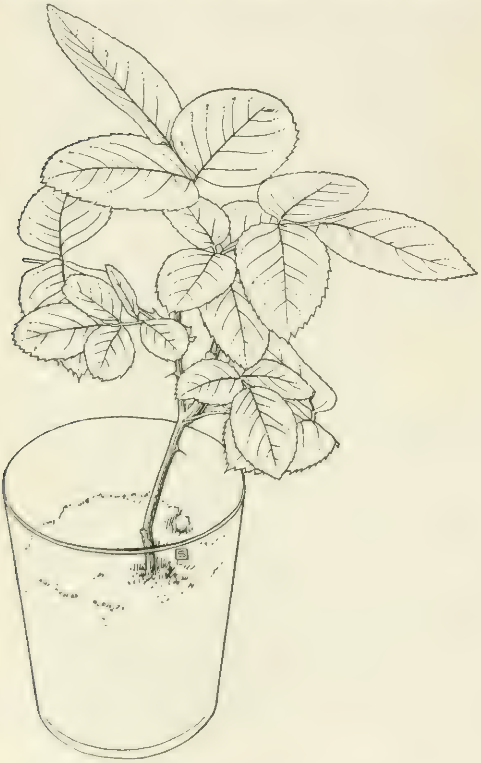

FIG. 1.—Rose cutting in rich garden soil. (One-half natural size.)

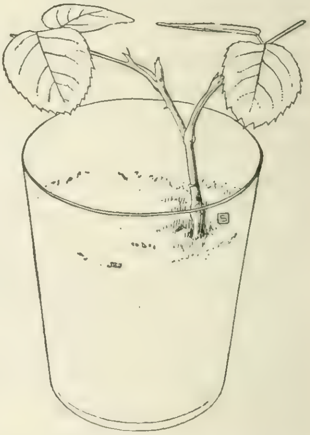

FIG. 2.—Rose cutting in peat mixture. (One-half natural size.)

the roots though long were slender and otherwise weak and bore no tubercles.

In the case of the blueberry plants the relative growth in the two soils took exactly the opposite course. At the end of the first week new root growth had begun in all the pots containing blueberry soil, while in those containing garden soil new root growth was apparent in only one. At the end of forty-four days vigorous root growth had taken place in the blueberry soil pots, and stem growth, which had been interrupted at the time of transplanting, was well under way again. In the garden soil, however, almost no root growth was discernible, the old leaves were strongly purpled and stem and leaf growth had not been resumed. Little attention was paid to these cultures during the summer of 1909, but the relative condition of the two is fairly illustrated in figures 5 and 6, from photographs taken November 22, 1909, after the leaves had fallen. The garden-soil pot contained only a few stray roots, and the slender stems were only 2 inches high. The pot containing blueberry soil was filled with a dense mass of roots, and although the plant had not been repotted when it needed repotting, the largest stem was nevertheless 11 inches long and the weight of that part of the plant above ground was fifty-one times that of the corresponding part of the garden-soil plant.

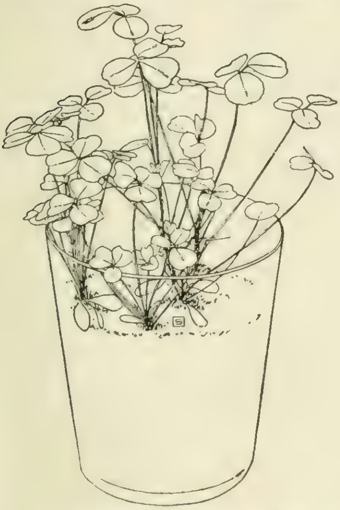

FIG. 3.—Alfalfa seedlings in rich garden soil. (One-half natural size.)

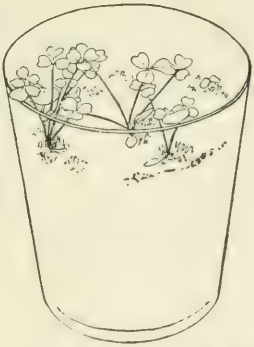

FIG. 4.—Alfalfa seedlings in peat mixture. (One-half natural size.)

(2) THE SWAMP BLUEBERRY DOES NOT THRIVE IN A HEAVILY MANURED SOIL.

In May, 1909, two healthy and vigorous blueberry seedlings were sent for trial to one of the agricultural experiment stations. They were set out in a soil that was known to be suitable for these plants, for old blueberry bushes had been growing there for several years.

The man who put the blueberry seedlings in the ground, however, misunderstanding the directions sent him, filled in the holes in which he set the plants with alternate layers of soil and well-rotted stable manure. The writer examined the plants on August 27, 1909, when they should have been either growing vigorously or, with mature foliage, ripening their wood for the winter. Instead they had lost nearly all their older leaves though still maintaining a feeble and spindling growth at the ends of the larger stems. The adjacent old bushes growing in precisely the same soil, except that it had not received the heavy application of manure, bore at the same time vigorous dark-green foliage and were ripening the wood of their stout twigs and laying down their flowering buds for the following year. The manured plants when dug up and examined showed no new root growth whatever in the manured soil outside the old earth ball, and most of the roots on the surface of the ball itself were dead.

Another experiment may be cited to show the injurious effect of heavy manuring. On December 22, 1908, six blueberry seedlings were transplanted into as many glass pots in a good blueberry soil, and six other seedlings were potted in the same manner, except that to each two parts of blueberry soil one part of well-rotted but unleached cow manure was added. At first the manured plants appeared, superficially, to be doing better than those not manured, for in the former the production of new leaves and the continued growth of the stem tip

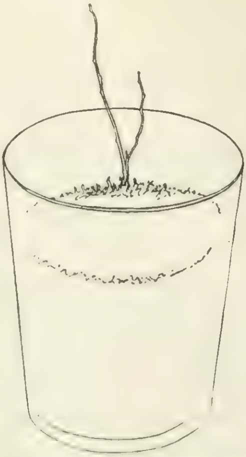

FIG. 5.—Blueberry seedling in rich garden soil. (One-half natural size.)

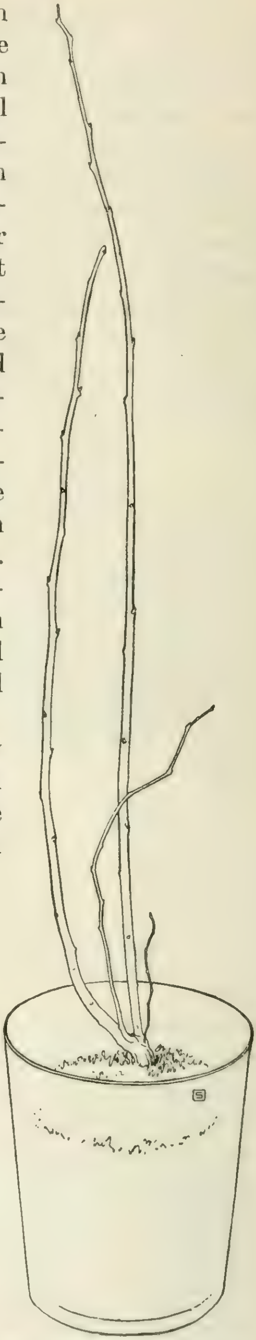

FIG. 6.—Blueberry seedling in peat mixture. (One-half natural size.)

were not interrupted by the potting, while in the plants not manured there was a temporary but definite stopping of stem growth immediately after the potting. The apparent superiority of growth in the manured plants, above ground, continued for about three weeks. Below ground, the roots of the two cultures showed directly opposite results. In the plants without manure, new root growth began a few days after potting. At the end of three weeks the development of an extensive root system was well under way and the plants were nearly ready for a period of vigorous stem growth. In the manured plants, however, either no root growth took place or only a slight amount, the new rootlets being fewer, shorter, and stouter than in normal plants. The old rootlets turned brown and appeared to be dead or dying. (See p. 64.) At the end of five weeks the growth of the tops was very slow. About ten days later, on February 6, a bright warm day, the lower leaves on three plants withered, and within a few weeks all six of the manured plants were dead.

(3) THE SWAMP BLUEBERRY DOES NOT THRIVE IN A SOIL MADE SWEET BY LIME.

In its natural distribution the blueberry, like almost all plants of this and the heather family, avoids limestone soils. The fertile limestone areas of western New York, of Ohio, of Kentucky, and of Tennessee lack the blueberry, the huckleberry, the laurel (*Kalmia latifolia*), and the trailing arbutus (*Epigaea repens*). The State of Alabama, as described by Charles Mohr in volume 6 of Contributions from the United States National Herbarium, is traversed from east to west in the general latitude of Montgomery by a strip of dark calcareous soil, 35 to 45 miles in width, the so-called "black belt," which constitutes the great agricultural region of the State. The noncalcareous areas north and south of this strip have in their forests a characteristic undergrowth of blueberries and closely related plants, including huckleberries, farkleberries, and deerberries. In the intermediate belt of black limestone soil, just described, the plants of blueberry relationship are almost wholly wanting.

In an article entitled "The Soil Preferences of Certain Alpine and Subalpine Plants,"[a] Mr. M. L. Fernald discusses the natural distribution of over 250 species of plants found in the cold parts of the northeastern United States and Canada. All the blueberries he enumerates, five species, avoided calcareous soils, and the other plants of the blueberry and heather families almost without exception occurred likewise on noncalcareous formations.

The writer's own experiments in growing blueberries in limed soils have not proceeded with the same smoothness as some of his other experiments, but the results, though at first misleading, have uniformly been exceedingly instructive, though not always in the direction originally contemplated, and in the end have been fully conclusive.

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[a] Rhodora, vol. 9, 1907, pp. 149–193.

On May 26, 1908, six blueberry seedlings were potted in six 14-ounce drinking glasses in a good peaty blueberry soil, in which, however, 1 per cent of air-slaked lime[a] had been mixed immediately before the potting was done. Six other plants were similarly potted, but without the addition of lime. The unlimed plants grew normally. The younger leaves of the limed plants, however, began to wilt the same day on which they were potted. On June 1 all the leaves on all six plants were withered, though parts of the stems were still green and plump. The leaves did not turn purplish or yellowish, as is usual with sickly blueberry plants, but either retained their green color after withering or turned brown. No new root growth took place in any of the limed pots, and by July 10 all the plants were dead.

Another series of six plants, also potted on May 26, 1908, but in a sterile soil containing no peat, by accident received a very small amount of lime. Most of the leaves on these plants withered during the first few days, but the plants subsequently recovered and made as good growth as could have been expected from the general character of their soil.

From these experiments the writer concluded that the blueberry was exceedingly sensitive to lime and that the slightest admixture of it in the soil would be immediately fatal to the life or at least the health of a blueberry plant. This conclusion, however, was erroneous, as subsequent experience showed. This first experiment may therefore be dismissed with the explanation that in all probability the immediate collapse of the plants was due to a caustic effect of the lime used. In none of the later lime experiments did this immediate collapse occur and in none was the lime so applied that it came into contact with the blueberry roots while in a caustic condition.

Still laboring under an erroneous conception of the supersensitiveness of the blueberry plant to minute quantities of lime, the writer, desiring to produce fresh examples of this phenomenon, in November, 1908, placed a very small quantity, a few milligrams, of air-slaked lime on the surface of the soil in each of three 2-inch pots containing a small blueberry plant. No effect was produced either at first or for several weeks. On December 19, 1908, a large surface application of carbonate of lime was made to the same three plants, a gram to each pot, and the lime was washed down with water. The expected collapse did not occur. The limed plants continued to grow as luxuriantly as their unlimed neighbors. The conclusion was reached that the reason why the growth of the plants had not been affected was because the lime had not penetrated sufficiently into the soil. Another and more drastic experiment was therefore determined upon.

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[a] Computed on the dry weight of the soil.

On March 10, 1909, six blueberry plants in 4-inch pots containing a good blueberry soil were set apart from their fellows and watered with ordinary limewater, a saturated solution of calcium oxid, 1.25 grams per liter of water. The applications made were of such an amount that the soil in the pot was thoroughly wetted each time, and usually a small excess quantity ran through the hole in the bottom of the pot.

For more than seven months, until October 22, 1909, these pots received no other water than limewater. During this period the plants continued to grow in a normal manner, their average height increasing from 4½ to 14 inches. The lime appeared to have no deterrent effect whatever on the growth of the plants. A computation based on the total amount of limewater used showed that each pot must have received about 18 grams of lime. An analysis of the soil in one of the pots after the limewater applications had ceased gave 14 grams. This amount was enormous, considered from the standpoint of agricultural usage. The soil, which had about one-third the weight of an ordinary soil, was over 8 per cent lime. This is the equivalent of about 25 tons of lime per acre mixed into the upper 6 inches of the soil.

Now, it was already known from the experiment described on page 23 that in this soil when containing as much as 1 per cent of lime blueberry plants should either die or barely remain alive. As a matter of fact these limewater plants were making excellent growth. A careful examination of the contents of one of the pots was then made. The surface of the soil was covered with a hard gray crust of lime. Immediately underneath for a depth of about half an inch the soil was black and contained no live blueberry roots. There was a zone of the same black rootless soil along the wooden label that reached from the top to the bottom of the pot. In all other parts of the dark-brown peaty soil there was a dense mass of healthy roots, which reached down also into the open spaces among the broken crocks in the bottom of the pot. The lime appeared to have penetrated only into the superficial portions of the soil. A chemical test showed that the black rootless layer was densely impregnated with lime, while the brown peaty portion containing the growing roots still gave the acid reaction that was characteristic of the whole potful of soil before the limewater applications began.

Since all the water that the limeless root-bearing portion of the soil had received during the preceding seven months had come from the limewater applications, it was evident that the lime contained in the limewater had been deposited in the upper layers of the soil. The following laboratory experiment confirmed this. A small quantity of the acid peaty soil used in growing blueberries was placed in a glass vessel and moistened. Then dilute limewater reddened by the addition of phenolphthalein, a substance giving a delicate color test for alkalies such as lime, was stirred into the soil and the mixture poured into an ordinary paper filter. The water came through the filter without a trace of red color, showed none after boiling, to drive off any possible carbonic acid, and when tested with ammonia and ammonium oxalate showed not a trace of lime. The precipitation of the lime had been complete and practically instantaneous. Only ten seconds had elapsed between the time when the limewater was added to the soil and the time when the liquid entirely free from lime began to drop through the filter.

In order to ascertain whether a large part of the lime in the limewater used on the plants may not have passed through the pots by running down the partially open channel along the label, some limewater was poured upon the surface of one of the pots. The excess water that soon began to drip through the bottom of the pot was tested for lime. It was found that while the limewater poured into the pot contained 0.1014 per cent of lime, the water that came through contained only 0.0046 per cent. In other words a pot of soil that for over seven months had been used essentially as a limewater filter still continued to extract over 95 per cent of the lime contained in the limewater that was passed through it, notwithstanding the fact that there was a partially open channel down one side of the pot. It is believed that had the soil been evenly compacted in the pot no lime whatever would have been able to pass through, but that all would have been precipitated in the uppermost layers.

While the experiment has no important bearing on the subject of blueberry culture it is of very great significance in its bearing on the method of applying lime to acid soils in ordinary agricultural practice. A surface application of lime would have no appreciable effect in neutralizing the acidity of a soil unless the soil was so sandy or gravelly or otherwise open that the rain water containing the dissolved lime could run down through it practically without obstruction. A surface dressing of lime would have little effect in neutralizing the acidity of an old meadow or pasture. To secure full action of the lime, as now generally recognized in the best agricultural practice, requires its intimate mixing with the soil, such as can be accomplished by thorough harrowing, especially after putting the lime beneath the surface with a drill. A full discussion of the physical reasons for the deposition of the lime in the upper layers of the soil, when not worked into it mechanically, is given in Bulletin 52 of the Bureau of Soils, published in 1908.

Among the experiments with blueberry seedlings in different soil mixtures started on December 22, 1908, was one in which six plants were set in glass pots in a peaty soil thoroughly intermixed with 1 per cent of carbonate of lime. The first difference that showed between these and unlimed plants in the same soil was the much feebler root growth of the limed plants. This was followed by an evident tendency toward feebler stem growth. The relative condition of the two cultures on April 13, 1909, is shown by photographs of representative plants reproduced as figures 7 and 8. The later progress of this experiment was interrupted, however, and its average results vitiated because the roots of some of the limed plants found their way through the holes in the bottom of the pots and obtained nourishment from the unlimed material in which the pots were plunged. Such plants made nearly as good growth as the unlimed plants. On November 27, 1909, there remained only one of the limed plants whose roots were all inside the pot. This plant was feeble and small, its stem being only 2½ inches high. Its inferiority to the unlimed plants was almost as conspicuous as that of the garden-soil plants described on page 17 and illustrated in figure 5.

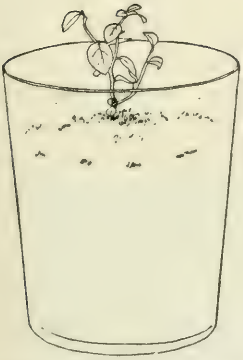


FIG. 7.—Blueberry seedling in peat mixture limed. (One-half natural size.)

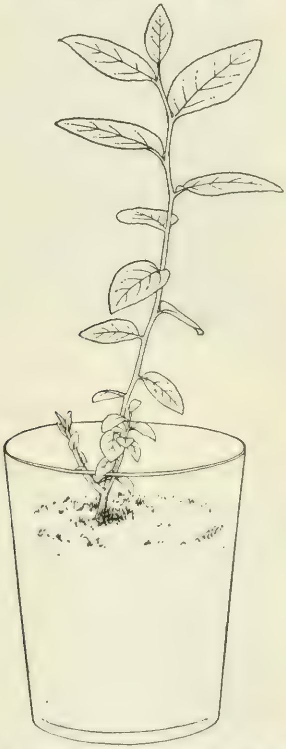


FIG. 8.—Blueberry seedling in peat mixture unlimed. (One-half natural size.)

(4) THE SWAMP BLUEBERRY DOES NOT THRIVE IN A HEAVY CLAY SOIL.

In its natural geographic distribution the blueberry shows an aversion to clay soils. Its favorite situations are swamps, sandy lands, or porous, often gravelly loams. When a blueberry plant grows upon a clay soil it is usually found that its finer feeding roots rest in a layer of half-rotted vegetable matter overlying the clay. Often in such situations the dense covering of interwoven rootlets and dark peatlike soil may be ripped from the surface in a layer little thicker than a door mat and of much the same texture. The roots of the blueberry do not penetrate freely into the underlying clay.

In greenhouse cultures the blueberry shows the same aversion to clay soils. Various series of blueberry seedlings were potted on May 26, 1908, in different soils in ordinary large drinking glasses. For one set of six plants a stiff clayey soil was used, such as is common in the neighborhood of Washington, D. C. The soil in the glass was mulched to the depth of nearly an inch with half-rotted leaves. In another six glasses were set six similar plants in a peat soil, the surface mulched in the same way as the others.

In other experiments with this clay soil in earthen pots, the growth of the plants had always been poor. The present experiment was no exception. But the feature of greatest interest was the behavior of the roots. Plate I, from photographs taken October 5, 1908, shows the root systems of typical plants in the two soils. In the clay soil almost no root development took place, and in the illustration no roots are visible. The interrupted black lines in the clay are tunnels made by larvæ or other animals. In the moist leaf mulch covering the clay, however, the plant developed its roots extensively. Some of the plants, probably because they were set too deeply in the clay when the potting was done, failed to send their roots up into the mulch, and such plants were much inferior in their growth to those that found the rotted leaves. In the other glass is shown the normal root growth of a blueberry in a soil suited to it.

(5) THE SWAMP BLUEBERRY DOES NOT THRIVE IN A THOROUGHLY DECOMPOSED LEAF MOLD, SUCH AS HAS A NEUTRAL REACTION.

It had been found in earlier experiments that certain soils composed in part of imperfectly rotted oak leaves were good for growing blueberries. On the supposition that the more thoroughly rotted this material was the better suited it would be for blueberry growing, a quantity of old leaf mold was secured for an experiment. The mold was black, mellow, and of fine texture. The mixed oak and maple leaves from which it was derived had been rotting for about five years, until all evidences of leaf structure had disappeared. It had the same appearance as the black vegetable mold that forms in rich woods where trilliums, spring beauty, and bloodroot delight to grow.

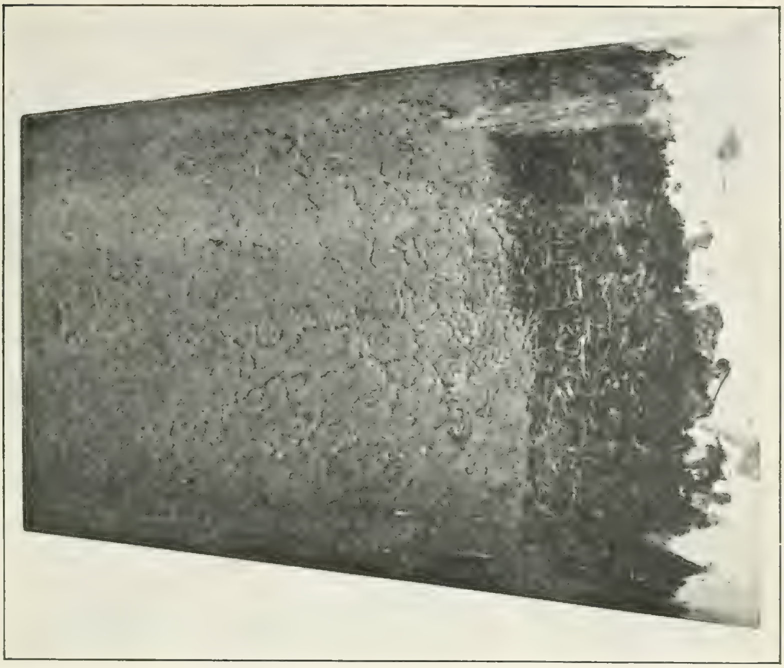


FIG. 1.—ROOT GROWTH OF A BLUEBERRY PLANT IN CLAY MULCHED WITH LEAVES.
(Natural size.)

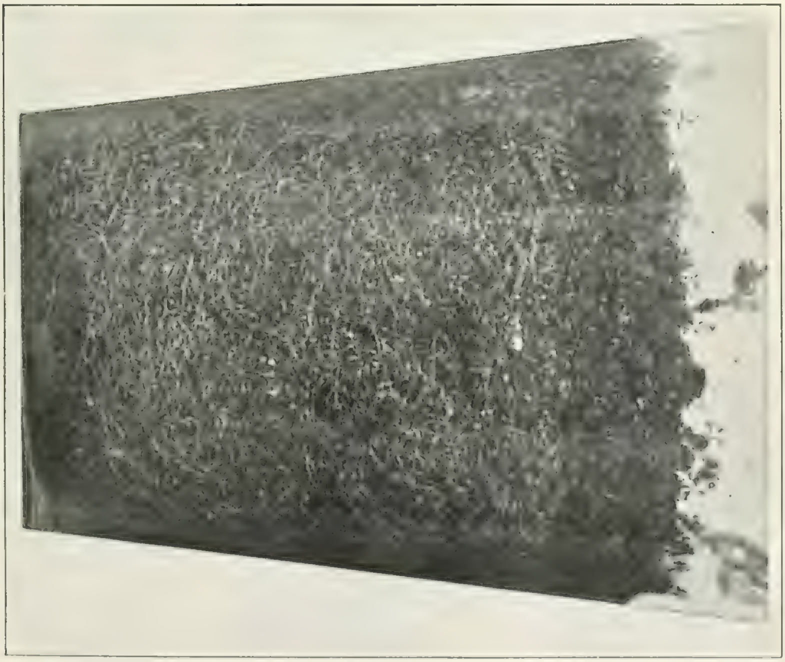


FIG. 2.—ROOT GROWTH OF A BLUEBERRY PLANT IN PEAT.
(Natural size.)

was 6 inches, and at the end of the season 12½ inches. In the second lot, in which the proportion was peat 3, mold 5, sand 1, and loam 1, the average height on May 29 was 4½ inches, and at the end of the season 11¾ inches. It will be observed that these two lots of plants are intermediate in their growth between the first two and that in all four lots the poverty of growth is roughly proportional to the amount of leaf mold used in the soil.

That the weak growth of the plants in leaf mold was not caused by a compacting of the soil and a lack of aeration, due to too small a proportion of sand in the mixture, is shown by still another lot of 25 plants which were potted in a soil mixture having the proportion of mold 6, sand 3, and loam 1. These plants averaged only 4 inches in height on May 29 and 6¼ inches at the end of the season. They grew even less, therefore, than the plants with only 1 part of sand and 8 parts of mold.

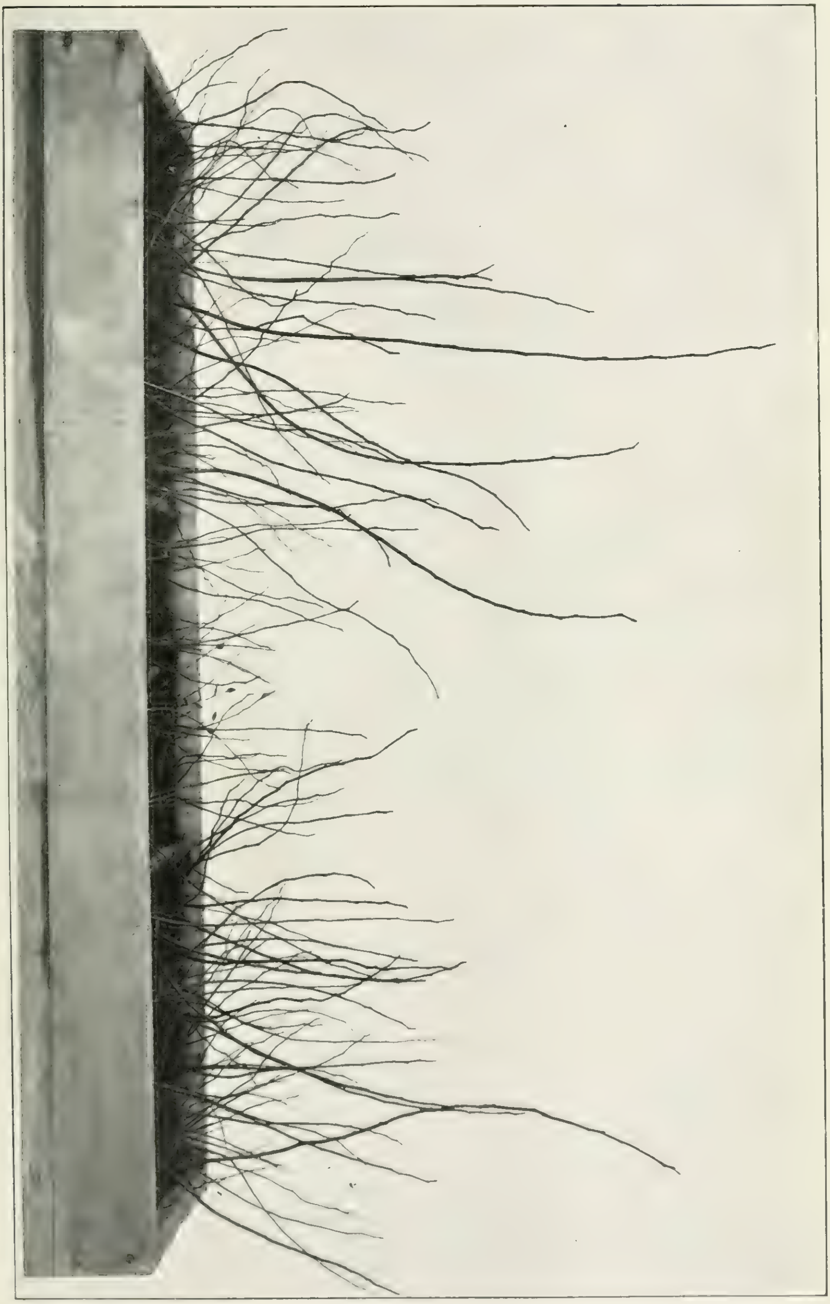
In Plate II, from a photograph made in the winter of 1909–10, is shown a flat divided into three parts and set on February 10, 1909, with blueberry seedlings of uniform size. The soil in the middle compartment is a mixture of leaf mold 8 parts, sand 1 part, and loam 1 part. In the compartment to the left the soil is in the proportion of kalmia peat 8, sand 1, and loam 1; and in the right-hand compartment, kalmia peat 4, leaf mold 4, sand 1, and loam 1. It will be observed that the greater the amount of leaf mold the poorer the growth of the blueberry plants.

The reason for the unexpected deleterious effect of leaf mold, as shown by these experiments, is given on page 29 and further discussed on page 35.

(6) THE SWAMP BLUEBERRY DOES NOT THRIVE IN SOILS HAVING A NEUTRAL OR ALKALINE REACTION, BUT FOR VIGOROUS GROWTH IT REQUIRES AN ACID SOIL.

The consideration of this statement requires first an understanding of the means used to determine whether a soil is acid or alkaline. The simplest means is the litmus test.

While one may become sufficiently expert in the use of the litmus test to form a fair judgment of the degree of alkalinity or acidity in a soil, an exact determination requires some different method. It was found that for the weak acids prevalent in the peat soils to the examination of which the present experiments led, the phenolphthalein test was the most satisfactory. If a few drops of phenolphthalein indicator be added to a solution, the solution, if alkaline, turns instantly pink, and if acid or neutral its color does not change. The application of this phenomenon to the determination of the degree of acidity of an acid solution is as follows: A definite amount of the solution, usually 100 cubic centimeters, is placed in a beaker, a few drops of an alcoholic solution of phenol-



BLUEBERRY SEEDLINGS IN PEAT AND LEAF MOLD.

(One-sixth natural size.)

phthalein are added, and into this is stirred drop by drop from a graduated glass tube provided with a stopcock, known as a burette, a measured amount of some alkaline solution of known strength, commonly a one-twentieth normal solution, as it is known to chemists, of sodium hydrate. When a sufficient amount of the sodium-hydrate solution has been dropped into the beaker, the acidity of the acid solution becomes neutralized and it turns pink. A reading is made on the burette showing the exact amount of the sodium-hydrate solution used in effecting the neutralization. From this reading is computed the degree of acidity expressed in fractions of a normal acid solution. Now 100 c. c. of a normal acid solution would require for its neutralization 100 c. c. of a normal solution of sodium hydrate, or 2,000 c. c. of a one-twentieth or 0.05 normal solution. In a test of one of the acid nutrient solutions used in the blueberry cultures, 18 c. c. of a 0.05 normal solution was required to neutralize the acidity of 100 c. c. of the acid solution. Since 18 c. c. of a 0.05 normal solution is the equivalent of one-twentieth that amount, or 0.9 c. c. of a normal solution, the degree of acidity of this acid solution is 0.009 normal. It requires an equal amount of a 0.009 normal alkaline solution to neutralize it.

In applying this phenolphthalein test to soils the same scale is used. A soil is regarded as having normal acidity when the acid existing in a gram of the soil if dissolved in 1 c. c. of water gives a normal acid solution. If a soil were described as having an acidity of 0.02 normal, it would mean that the extract of 100 grams of it in 100 c. c. of water would be a 0.02 normal acid solution; that is, that 100 c. c. of the solution would contain 2 c. c. of a normal acid solution.

The method of extraction followed for all the soil acidity tests given in this paper is as follows: The soil is first air dried at an ordinary room temperature. Ten grams are then weighed out, shaken thoroughly with 200 c. c. of hot water, and allowed to stand over night. In the morning 100 c. c. is filtered off and boiled to drive away any carbon dioxid present. The solution is then titrated with a 0.05 normal solution of sodium hydrate, using phenolphthalein as an indicator. All the tests were made by Mr. J. F. Breazeale, of the Bureau of Chemistry, to whom the writer is greatly indebted for many courtesies and suggestions on the chemical side of the experiments.

The expression "normal solution" used in this paper, it must be understood, is the normal solution of chemists, not of surgeons. Surgeons use the expression "normal salt solution" to describe a certain weak solution of common salt in water which has the same osmotic pressure as the blood. A normal solution in chemistry is a solution of certain fixed strength, or concentration, based on the molecular weight of the substance under consideration. Normal solutions of the various acids have the same degree of acidity. Normal solutions of alkaline substances are equal to each other in alkalinity. A measured amount of a normal solution of an acid will exactly neutralize an equal amount of a normal solution of an alkaline substance.

In considering the degree of acidity from the standpoint of the sense of taste it is convenient to remember that the juice of an ordinary lemon is very nearly a normal solution of citric acid. The juice of the lemon contains usually from 6 to 7 per cent of citric acid. A normal solution of citric acid is 6.4 per cent. When the juice of a lemon is diluted to about ten times its original bulk, as in a large drinking glass, one has approximately a 0.1 normal acid solution. When diluted to 100 times, making about a 0.01 normal solution, there remains only a faint taste of acidity. The acidity of water after standing long in contact with peat in a barrel sometimes reached 0.005 normal. Bog water, or peat water, is sometimes appreciably acid to the taste.

Returning now to a consideration of the statement that the swamp blueberry does not thrive in a neutral or alkaline soil an experiment in this direction may first be cited. The experiment was made with twelve small glass pots, each containing a blueberry seedling. The soil in the pots was a clean river sand. The plants had been in these pots for eight weeks, watered with tap water. The amount of nourishment they had received during this time was therefore very small, especially since, when transplanted into the pots, all the soil of the original seed bed had been carefully removed from the roots. Nevertheless during these eight weeks all the plants had made extensive, even luxuriant, root growth. The tops, however, had made no growth. There had been complete stagnation or withering of the youngest leaf rudiments, and the mature leaves became and remained deeply purpled.

Beginning on February 17, 1909, eight weeks after the plants had been potted in the sand, as already stated, five of the pots were watered with an acid nutrient solution made up, in accordance with the advice of Mr. Karl F. Kellerman, of the Bureau of Plant Industry, as follows:

Potassium nitrate (KNO_3)	1.0 gram.
Magnesium sulphate ($MgSO_4$)	0.4 gram.
Calcium sulphate ($CaSO_4$)	0.5 gram.
Calcium monophosphate ($CaH_4P_2O_8$)	0.5 gram.
Sodium chlorid ($NaCl$)	0.5 gram.
Ferric chlorid ($FeCl_3$)	Trace.
Water	1,000 c. c.

This solution gave an acidity test of 0.012 normal.

Five other plants from the same twelve were watered with an alkaline nutritive solution of the following composition:

Potassium nitrate (KNO_3)	1.0 gram.
Magnesium sulphate ($MgSO_4$)	0.4 gram.
Calcium sulphate ($CaSO_4$)	0.5 gram.
Potassium diphosphate (KH_2PO_4)	0.4 gram.
Sodium chlorid ($NaCl$)	0.5 gram.
Ferric chlorid ($FeCl_3$)	Trace.
Water	1,000 c. c.

By the addition of a sufficient quantity of sodium hydrate the reaction of this solution was made alkaline to the degree of 0.006 normal.

Two of the twelve plants were left as checks, being still watered with tap water.

On March 25, thirty-six days after the watering began, the five plants fed with the acid nutritive solution were restored to a nearly normal green color, and all had begun to put out healthy new growth. The two check plants watered with tap water were still red-purple and stagnant. Of the five plants watered with the alkaline nutrient solution, three were stagnant and somewhat purplish, one was dying, and one was dead.

Figures 9 and 10, from photographs taken on April 15, 1909, show a typical stagnant plant that had been watered with the alkaline solution, and a typical plant watered with the acid solution which had begun to make new growth from the summit of the old stem and was pushing out a vigorous new shoot from the base. The experiment was terminated not long afterwards, but there was every prospect that had it been continued the acid-fed plants would soon have made growth comparable with that shown in figure 8 (p. 23).

Looking toward the acidity or alkalinity of the other cultures thus far cited, it may be stated that the rich garden soil described on page 14, which was so remarkably deleterious to blueberry seedlings, was alkaline. The rose cuttings and the alfalfa, which grew so well in that mixture, much prefer a somewhat alkaline soil. Indeed, alfalfa can not be grown with any degree of success in any soil except one with an alkaline reaction. When grown in the humid eastern United States alfalfa is rarely successful, except on calcareous soils, unless the natural acidity of the soil has been neutralized by suitable applications of lime.

The limed soil, deleterious to blueberry plants, described on page 23, gave a neutral reaction with phenolphthalein.

The heavy clay soil described on page 24, in which blueberry plants made very little growth, was neutral.

The thoroughly decomposed leaf mold described on pages 24 to 26, which was shown by experiment to be markedly deleterious to the blueberry, was distinctly alkaline. A chemical analysis of this mold showed that it contained 2.86 per cent of calcium oxid.

The good blueberry soils in all the experiments were acid, the acidity at times of active growth varying from 0.025 normal down to 0.005 normal.

It is of interest and suggestive of utility in indicating the acid or nonacid character of soils to record that in the case of the alkaline leaf mold described on page 24 the surface of the soil in all the pots became covered in a few months with a growth of a small moss identified through the courtesy of Mrs. N. L. Britton as *Physcomitrium immersum*. On the surface of acid kalmia-peat soils the characteristic green growth consisted of microscopic algæ, accompanied often by fern prothallia and other mosses, but never Physcomitrium.

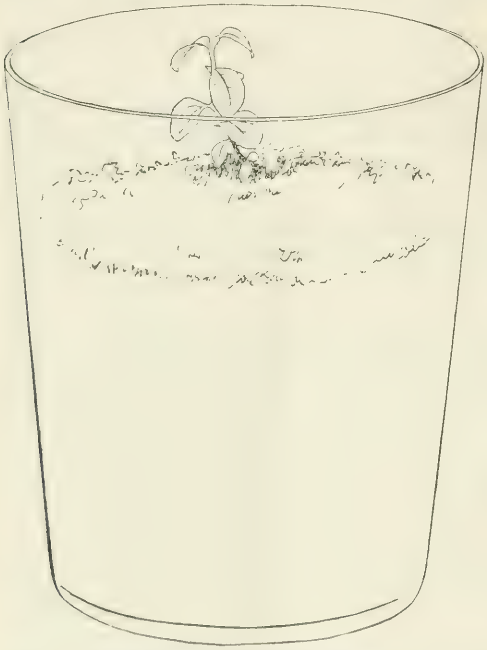


FIG. 9.—Blueberry seedling fed with alkaline nutrient solution. (Natural size.)

The natural distribution of blueberries and their relatives indicates their close adherence to acid soils. They occur in abundance throughout the sandy Coastal Plain of the Atlantic seaboard. They occur generally through the cool humid hill lands of New England. They occur in sandy pine barrens and peat bogs throughout the eastern United States. They are absent, on the contrary, from limestone soils, rich bottom lands, and rich woods, where the soils are neutral or alkaline. In the lower elevations of the whole subarid West, where acid soils are almost unknown, these plants do not occur. Within reach of the fogs and heavy rainfall of the Pacific coast or on the higher mountains of the interior, where conditions favor the development of acid soils, blueberries occur again in characteristic abundance.

From an examination of the reports of those who have attempted at the agricultural experiment stations to domesticate and improve the blueberry, it is evident in the light of the present experiments that the primary reason for these failures was that they did not recognize soil acidity as a fundamental requirement of these plants. It was perhaps natural to give the blueberry the same garden culture that when applied to other bush fruits has resulted in their distinct improvement. But the ordinary garden operations tend to make even an acid soil neutral or alkaline, and in such a soil the blueberry does not thrive.

The death and decay of blueberry roots, with which the injurious effect of alkaline soils is associated, are discussed on pages 64 and 65.

(7) THE FAVORITE TYPE OF ACID SOIL FOR THE SWAMP BLUEBERRY IS PEAT.

Although the swamp blueberry sometimes grows on upland soils its typical habitat, as its name implies, is in swamps or bogs. The cranberry, it is well known, is cultivated almost exclusively in bogs. In clearing bog land preparatory to the planting of cranberries one of the necessary precautions is to remove all roots of the swamp blueberry. If the roots are allowed to remain in the ground, they send up vigorous shoots, and these, unless pulled, develop into robust plants which occupy the ground to the great injury of the cranberries. Large, healthy, and productive bushes of the swamp blueberry are frequent, almost characteristic, inhabitants of the uncultivated borders of cranberry bogs.

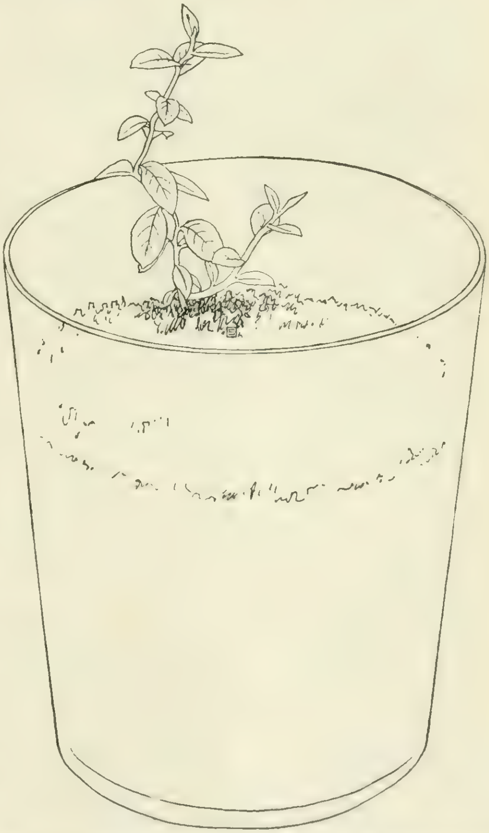


FIG. 10.—Blueberry seedling fed with acid nutrient solution. (Natural size.)

Peat bogs, in the conception of geologists, are incipient coal beds. The transformation of peat into coal occupies very long periods, perhaps some millions of years. Peat is made up chiefly of vegetable matter, the dead leaves, stems, and roots of bog plants which are only partly decayed. Their full decay is prevented primarily by the presence of water, which keeps away the air. The bacteria, fungi, and other organisms by which ordinary decomposition progresses can not live under this condition and decay is suspended. The acids developed by this vegetable matter in the early stages of its decomposition are also destructive to some of the organisms of decay, especially bacteria. These acids act therefore as preservatives and greatly assist in preventing decomposition. So effective are these conditions of acidity and lack of oxygen, assisted in northern latitudes by low temperature, which is also inimical to the organisms of decay, that bogs sometimes preserve for thousands of years the most delicate structures of ferns and mosses.

Tests have been made of the acidity of typical peat bogs in New England where swamp blueberries are growing. These peats were always found to be acid and the degree of acidity was within the range found satisfactory for blueberry plants in pot cultures.

The reason why peat is a particularly satisfactory type of acid soil for blueberries is, apparently, because the acidity of peat is of a mild type, yet continually maintained.

Not all peats are acid. About the larger alkaline (but not destructively alkaline) springs of our southwestern desert region are deep deposits of rather well-decayed vegetable matter that must be classed as peat. The characteristic vegetation growing on these peats is tule (*Scirpus occidentalis* and *S. olneyi*). The water of one of the great tule swamps of the West (Lower Klamath Lake in southern Oregon), which contains thick beds of peat formed chiefly from *Scirpus occidentalis*, has been examined recently by Mr. J. F. Breazeale, at the request of Mr. C. S. Scofield. It was found to contain sodium carbonate, and the peat gave a distinctly alkaline reaction.

The peat formed about marl ponds in the eastern United States is also, in all probability, alkaline unless formed at a sufficient distance from the lime-laden water to be beyond the reach of its acid-neutralizing influence.

Such alkaline peats, while not actually tried, are believed from other experiments to be quite useless for growing blueberries. Certain it is that neither blueberries nor any of their immediate relatives are found on these soils in a wild state. In the eastern United States, however, such alkaline peats are comparatively rare, and the use of the word "peat" conveys ordinarily the idea of acidity. All the soils used by gardeners under the name of peat are acid.

(S) PEAT SUITABLE FOR THE SWAMP BLUEBERRY MAY BE FOUND EITHER IN BOGS OR ON THE SURFACE OF THE GROUND IN SANDY OAK OR PINE WOODS.

In the vicinity of Washington deposits of bog peat are few and of limited extent, and the peat is thin. As a matter of fact no bog peat of local origin is used by the gardeners and florists of Washington. For growing orchids, ferns, azaleas, and other peat-loving plants, either peat shipped from New Jersey is used or a local product sometimes known as "Maryland peat." This material is not a bog peat at all, and since it is of very great interest in connection with these blueberry experiments, for it was the principal ingredient in a majority of the successful soil mixtures used, it is desirable that the reader have a comprehensive idea of its character.

Maryland peat, as brought to the greenhouses of the United States Department of Agriculture, consists of dark-brown turfs or mats, 2 to 4 inches thick, made up of partially decomposed leaves interlaced with fine roots. It is found in thickets of the American laurel (*Kalmia latifolia*) where the leaves of this shrub, usually mixed with those of various species of oak, have lodged year after year and the accumulated layers have become partly decayed.

The nature of the deposit may be easily comprehended by means of the accompanying illustrations. The photographs from which the illustrations were made were secured through the courtesy and skill of Mr. G. N. Collins, of the Bureau of Plant Industry. The photographs were made in the month of April, 1908, in a laurel thicket at Lanham, Md. After one photograph was made, the layer of leaves represented by it was removed and another photograph was taken showing the layer immediately underneath.

In Plate III, figure 1, is shown the top layer of the leaf deposit as it appeared in April, 1908, consisting of oak leaves of various species which fell to the ground in the autumn of 1907. The next underlying layer is shown in Plate III, figure 2. The laurel leaves here shown are those that fell in the summer of 1907. Laurel being an evergreen, its leaves are not shed in the autumn like those of the oaks. They remain on the bush until the new leaves of the following spring are fully developed and then the old leaves begin to fall. It is this circumstance of the fall of the oak and laurel leaves at different periods of the year that enables one to recognize the different layers and know their exact age. The third layer, shown in Plate IV, figure 1, consists of oak leaves of the autumn of 1906. This layer was moist and decomposition was well started. The presence of fungous growth is evident, as is also the excrement of various small animals. Myriapods, or thousand-legged worms, and the larvæ of insects must play a very important part under some conditions in hastening the decomposition of leaves. The fourth layer, Plate IV, figure 2, consisting of laurel leaves shed in the summer of 1906, is in about the same condition as the preceding layer. In the fifth layer, Plate V, figure 1, are shown the leaves of 1905, but the layer of oak leaves is not readily separable from the laurel. The rotted leaves crumble readily and decomposition has so far progressed that a few oak rootlets are found spread out between the flattened leaves. Plate V, figure 2, shows the rotted leaf layers of 1904 interlaced with the rootlets of laurel and oak. It is this root-bearing layer, 2 inches or more in thickness, of which

Maryland peat is composed. The lower portions of it reach a somewhat greater degree of decomposition than is here shown.

In a rich woods of the trillium-producing type, such as a fertile sugar-maple forest, one may observe that the leaves in rotting seldom retain their form longer than two years and that the line of demarcation between the thin leaf litter of the forest and the underlying woods mold is sharp and clear.

In the sugar-maple woods the decomposition of the leaves is rapid. In the Maryland or kalmia peat, as it may be called with more exactness, the decomposition is slow. The cause of this difference in the rate of decomposition is the difference of acidity in the two cases, and this in turn is dependent on the nature of the leaves and of the underlying soil, particularly whether the soil is acid or alkaline. A slight alkalinity in a soil greatly favors the decomposition of the leaves overlying it. An acidity as strong as that shown to occur in newly fallen oak leaves (see p. 62) can not help having a pronounced effect in maintaining the acidity of the lower leaf layers; for it must be remembered that these acids are soluble in rain water, and are therefore continually leaching down from the upper through the lower layers of rotting leaves.

These upland leaf deposits, in which decomposition is retarded for many years, the writer regards as essentially peat, and to distinguish them from bog peats he would call them upland peats. An upland peat may be described as a nonpaludose deposit of organic matter, chiefly leaves, in a condition of suspended and imperfect decomposition and still showing its original leaf structure, the suspension of decomposition being due to the development and maintenance of an acid condition which is inimical to the growth of the micro-organisms of decay.

The use of the name "leaf mold," sometimes applied to this upland peat, should be restricted to the advanced stages in the decomposition of leaves, in which leaf structure has disappeared. True leaf mold, furthermore, is neutral or alkaline, so far as tested.

When kalmia peat is to be used for growing blueberries it should be piled and rotted for several months. An experience which emphasizes the need of this treatment is given on page 60. If stacked as soon as it is dug it usually retains sufficient moisture to carry the rotting forward, even if the stack is under cover.

Kalmia peat has proved to be a highly successful soil for growing blueberries. It has been tried both pure and in many mixtures, as will be described in the paragraphs beginning on page 51.

An upland peat formed of the leaves of scrub pine (*Pinus virginiana*) has also been tried for blueberry seedlings. They grow well in it.

Oak leaves, it is believed, rotted for one or two years would make a good blueberry soil. In the Arlington National Cemetery is a ravine

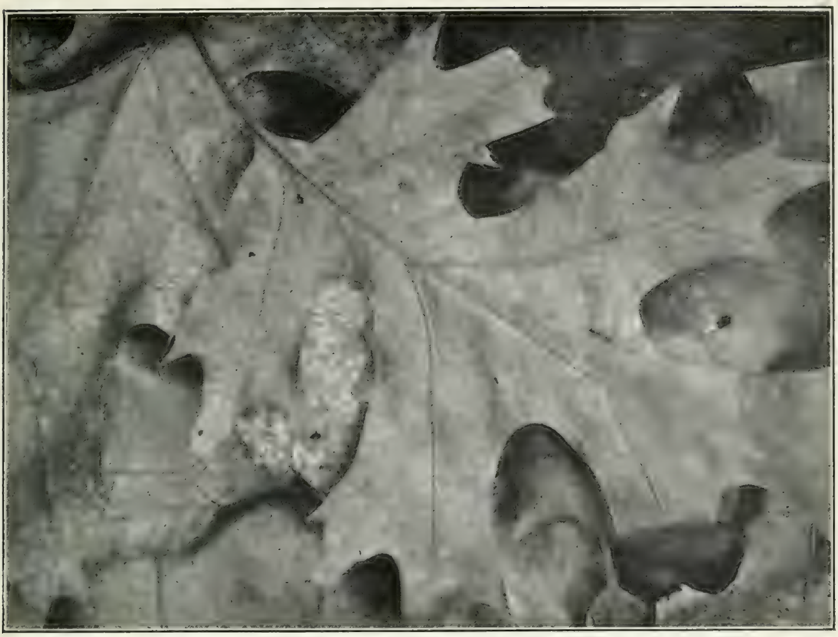


FIG. 1.—FORMATION OF KALMIA PEAT, TOP LAYER.

Oak leaves of the preceding autumn. (Natural size.)

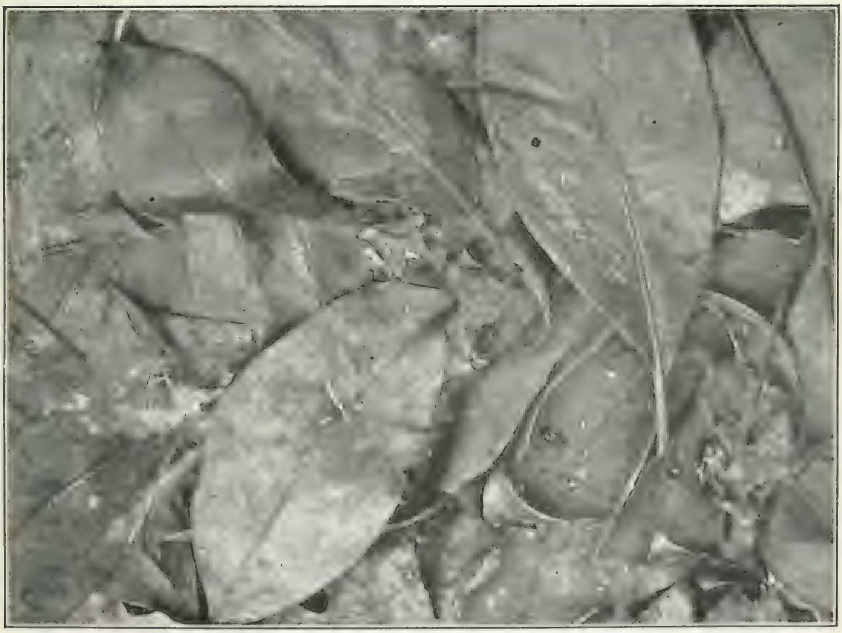


FIG. 2.—FORMATION OF KALMIA PEAT, SECOND LAYER.

Kalmia leaves of the preceding summer. (Natural size.)

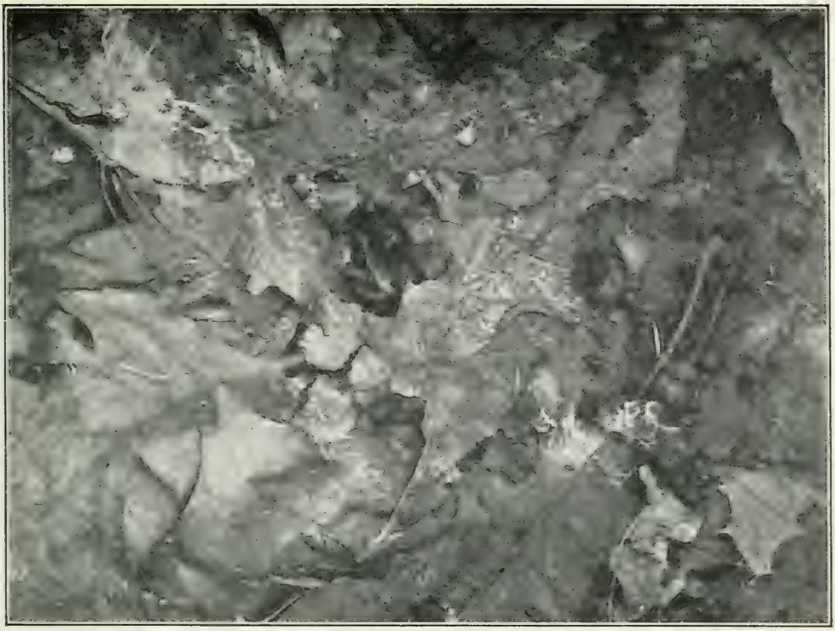


FIG. 1.—FORMATION OF KALMIA PEAT, THIRD LAYER.

Oak leaves 2 years old. (Natural size.)

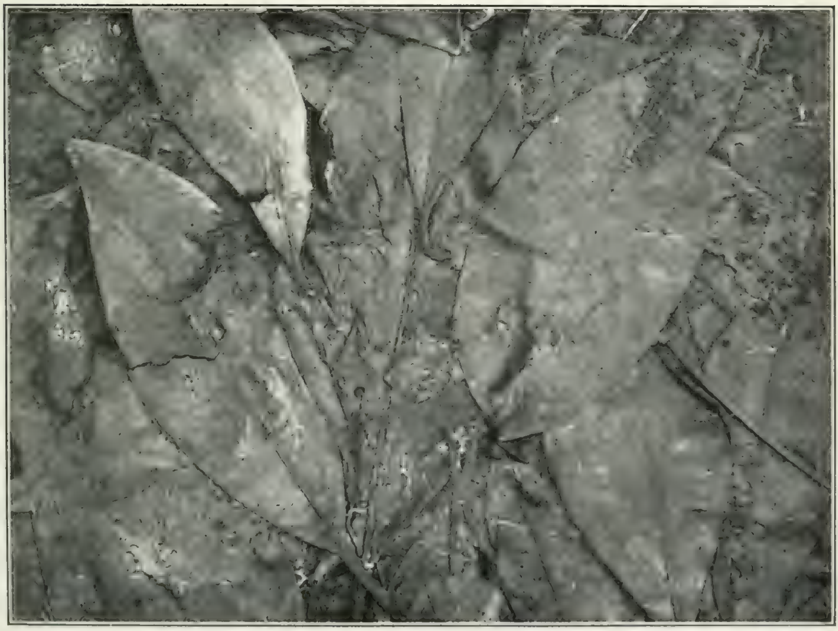


FIG. 2.—FORMATION OF KALMIA PEAT, FOURTH LAYER.

Kalmia leaves 2 years old. (Natural size.)

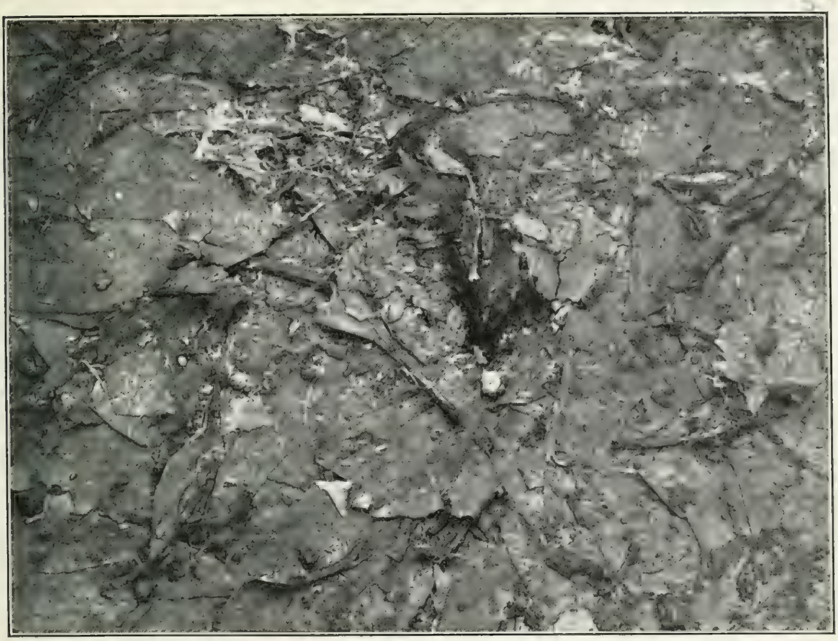


FIG. 1.—FORMATION OF KALMIA PEAT, FIFTH LAYER.

Mixed oak and kalmia leaves 3 years old. A few live rootlets of oak are shown. (Natural size.)

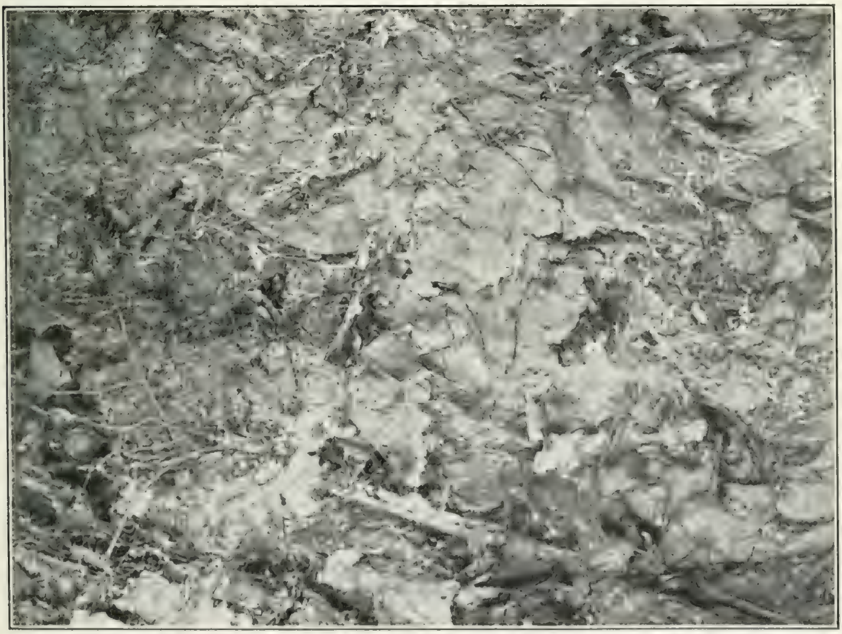


FIG. 2.—FORMATION OF KALMIA PEAT, SIXTH LAYER.

Mixed oak and kalmia leaves 4 years or more old interlaced with live rootlets of oak and kalmia. (Natural size.)

in which large quantities of leaves, chiefly oak, have been dumped for many years. Samples taken there in late November, 1909, show an acidity in the case of freshly fallen leaves of 0.4 normal; in leaves apparently 1 year old, 0.006; and in leaves about 2 years old, 0.002.

A condition of great interest was found in one of these piles of leaf mold which was several years old. It was mellow and black, and the evidence of leaf structure had disappeared. When submitted to the phenolphthalein test it proved to be alkaline, and upon chemical examination it was found to contain 3.55 per cent of lime (CaO). In this case decomposition had progressed so far, it is suggested, that the lime in the leaves, remaining constant in amount and probably having been changed to a more soluble state, had neutralized the remaining acidity. The material, then becoming alkaline, had proceeded to decompose with greater rapidity, until a real mold had been formed.

The condition here observed is doubtless the same as that which occurs in the drained bog, or so-called "muck," lands of Michigan. When first plowed they will grow only certain acid-resistant crops, such as buckwheat or potatoes, but later, as their acidity disappears, they come to attain a very high degree of fertility. It is probably a phenomenon of similar character which is taking place in the drained swamp lands of the lower Sacramento River in California, where the soil, which is already in a state of remarkable fertility, is becoming increasingly alkaline.

Here allusion may be made to another phenomenon, that of the occurrence of the swamp blueberry and certain other plants, such as the purple lady's-slipper (*Cypripedium acaule*) and the swamp honeysuckle (*Azalea nudiflora*), in two kinds of situations—one a peat bog, the other a sandy, well-drained, and often dry upland. The favorite explanation of this phenomenon among botanists is that these plants are naturally adapted to the drier situation and that in the bog they find a situation of "physiological dryness," or vice versa. While the existence of physiological dryness in peat bogs is not questioned, the explanation that a bog plant finds an upland situation congenial because it is dry certainly will not answer for the blueberry. Its occurrence in these two habitats is dependent on the acidity of both situations. These experiments have shown that no amount of dryness will make a blueberry flourish in an upland soil if that soil is not acid.

(9) FOR ACTIVE GROWTH THE SWAMP BLUEBERRY REQUIRES A WELL-AERATED SOIL. CONVERSELY, THE SWAMP BLUEBERRY DOES NOT CONTINUE IN ACTIVE GROWTH IN A SOIL SATURATED WITH WATER.

In its natural distribution the swamp blueberry does not grow in the lower, wetter type of bog. In a typical leatherleaf (*Chamaedaphne calyculata*) bog, for example, the swamp blueberry is found either about the margin of the bog or on hummocks. In both these situations most of the roots of the blueberry bushes stand above the summer level of the water. When a bog has been built up by the growth of vegetation and the accumulation of the débris until the surface is above the summer water level, the swamp blueberry will occur generally over the bog.

An examination of blueberry plants occurring on hummocks and bog margins has shown that such roots as extend beneath the permanent summer water level bear few feeding rootlets or none at all.

In one experiment it was attempted to grow blueberry seedlings in water cultures containing various dissolved nutrients. It was found that the roots made no new growth, that the new leaves were few and small, and that the general health of the plants was not good, whatever the character of the nutrient substances in the solutions. It was frequently observed also in the various soil cultures, particularly those in undrained glass pots, that the continued saturation of the soil with water reduced the root growth and enfeebled the whole plant. Continued excessive watering of potted blueberry plants was always found injurious.

The observations just recorded must not be understood to mean that submergence of the roots is always injurious to the swamp blueberry. In winter and early spring the water level of bogs containing blueberries often remains high enough for several months to completely submerge the whole root system of the plants. On the lower end of the Wankinco cranberry bog near Wareham, Mass., are some native bushes of the swamp blueberry, the roots of which have been submerged in 3 feet of water from December to May each year for about twenty years. These bushes when observed in September, 1909, gave every evidence of vigor. Their twig growth was of good length and thickness, their foliage was dense and of a healthy color, their flowering buds for the next year were fairly numerous, and the bushes were said to be as productive of fruit as neighboring bushes on higher ground.

It would appear from these facts that, while submergence during the dormant period is not injurious to the swamp blueberry, its roots during their actively growing period must be kept above the water level so as to be well aerated.

(10) AERATION CONDITIONS SATISFACTORY FOR THE SWAMP BLUEBERRY ARE PREVALENT IN SANDY SOILS.

The experiment cited above on this page showed that blueberry seedlings having their roots suspended in nutrient solutions failed to make a normal growth even though the solutions were suitably acidulated. This failure was ascribed to lack of aeration. In another experiment, described on pages 28 and 29, it was shown that a similar nutrient solution when used to water a blueberry plant potted in sand produced a normal growth of both roots and stems. The sand furnished no appreciable nourishment and the only essential difference in the two cases was the abundant root aeration afforded by the sand culture. Sand is therefore regarded as having been shown experimentally to furnish conditions suitable for soil aeration.

In all the experiments in which blueberry seedlings were grown in sand cultures suitably acidulated, the root growth was good, even when very little nourishment was given the plant, and when fed with a weakly acid nutrient solution or with peat water the sand-potted plants always made a luxuriant root growth.

In their wild state blueberries are especially prevalent on the sandy soils of the Atlantic Coastal Plain, as well as on sandy plains and pine barrens in the interior. The drainage of such soils is good and their aeration is excellent.

(11) AERATION CONDITIONS SATISFACTORY FOR THE SWAMP BLUEBERRY ARE FOUND IN DRAINED FIBROUS PEAT.

Kalmia peat when in the original turfs or mats is full of small roots of oak, kalmia, and other plants. In that condition it is remarkably porous and well aerated. Pieces of these turfs were used with great success in the bottoms of pots, in place of crocks, to afford drainage. For a potting soil, however, kalmia peat can not easily be used until the soil has been shaken from the mass of roots or has been rubbed through a screen. Even in that condition the fragments of leaves and rootlets make the whole mass porous. A pot containing pure kalmia peat prepared by such rubbing often remains moist, yet well aerated, for days at a time without watering. This moisture condition is due to two remarkable properties of peat, its ability to hold a large amount of water, and the tenacity with which it clings to it.

Kalmia peat taken from the interior of a stack after it has remained several months under cover ordinarily contains 100 per cent of water, computed on the dry weight of the peat. Even with this very high water content a peat soil is in a beautiful condition of tilth, mellow, well aerated, and to the sight and touch apparently only moderately moist. Ordinary loam in a similar condition contains only about 18 per cent of water, and sand about 3 per cent. When saturated with water the moisture content of kalmia peat is about 500 per cent of its dry weight.

The ability of peat to retain its moisture depends in part on the gradual drying of the superficial layers and the consequent formation of a mulch, but more particularly is it dependent on a certain physical affinity that peat possesses for water. The comparative strength of this water-holding power in different soils may be tested by subjecting them to a powerful centrifugal force, which tends to throw the moisture out of the soil. The standard centrifugal force used is a thousand times the force of gravity. The percentage of moisture remaining in the soil after this treatment is known as the moisture equivalent of that soil. A test of kalmia peat made by Dr. Lyman J. Briggs, of the Bureau of Plant Industry, the originator of this method of measurement, showed a moisture equivalent of 142 per cent. as compared with about 30 per cent for clay, 18 per cent for loam, and 2 to 4 per cent for sand.

From what has been said it is evident that fibrous kalmia peat has physical characteristics that allow the soil to be amply aerated, while at the same time holding abundant moisture for the supporting of plant growth.

In this connection reference may be made to the influence of earthworms on potted blueberry plants. Late in the winter of 1908–9 it was noted that among the blueberry seedlings of 1907, which had been brought into the greenhouse, were several in which the growth was feeble, although others of the same lot were growing vigorously. It was noted also that the soil in the pots in which the feeble plants were growing contained earthworms, as evidenced by the excrement or casts deposited by them on the surface. The worms themselves were easily found by knocking the earth ball out of the pot, and the soil was seen to have been thoroughly worked over by the worms.

It was supposed at first that the soil (a mixture of peat 8, sand 1, loam 1) in the process of digestion to which it had been subjected in passing through the alimentary canal of the earthworms might have become alkaline and for this reason injurious to the blueberry plants. When tested with phenolphthalein, however, the soil in the pots containing earthworms and feeble plants was found to be of the same acidity as that in the pots containing no earthworms and with vigorously growing plants. Furthermore the fresh casts themselves were of a similar degree of acidity.

The texture of the soil, however, in the pots containing worms was very different from that in the others. It was plastic, very fine grained, almost clayey, the organic portion having been very finely ground evidently in passing through the gizzard and other digestive apparatus of the earthworms. The aeration of the soil in this condition must have been far poorer than in the coarser soil containing a large amount of leaf fragments not worked over by worms, and it may be that the difference in growth of the blueberry plants was due to the difference in aeration. It is not by any means certain, however, that the plants in the pots containing earthworms may not have been injured directly through the eating of their rootlets by the worms.

(12) AERATION CONDITIONS SATISFACTORY FOR THE SWAMP BLUEBERRY ARE FOUND IN MASSES OF LIVE, MOIST, BUT NOT SUBMERGED SPHAGNUM.

In some swamps the water level remains permanently above the general surface of the ground. When the swamp blueberry occurs in such situations it grows on hummocks the summits of which stand above the water during the growing season. Unless the water level is extremely variable or the ground is densely shaded, these hummocks are usually covered with a cushion of live sphagnum moss. It is a peculiarity of this moss that it absorbs water with great avidity; indeed, sphagnum is one of the most absorbent substances known. If one end of a nearly dry branch of sphagnum is brought into contact with a little water, the whole branch becomes wet almost instantly. The water rushes along with marvelous rapidity through the cells of the plant and especially through the interstices between the minute overlapping leaves. The white air spaces between the half dry leaves flash out of existence one after the other like candle flames in a gust of wind. The same ability to absorb water is characteristic of masses of this plant. If the lower part of a cushion of sphagnum is in contact with free water the fluid is conveyed from stem to branch and from plant to plant in sufficient amount to render the whole mass as wet as a sponge. When one squeezes a handful of such moss taken perhaps a foot or more above the source of moisture the water runs out in streams. A sample of live sphagnum with less moisture than usual but still with enough to maintain itself in a growing condition was found to contain 991 per cent of water, computed on the dry weight of the sphagnum, while saturated live sphagnum carried 4,005 per cent of water. On the basis of its dry weight, therefore, sphagnum contains about ten times as much water as peat, which itself contains about six times as much as ordinary loam and about thirty-five times as much as sand.

The innumerable extracapillary air spaces between the branches of sphagnum plants and between the plants themselves furnish good aeration, even when the individual branches are saturated with water. When the moisture is less the aeration is still better. The cushion of sphagnum on a hummock tends to build itself up by the gradual process of growth and decay to the maximum height to which it can convey the large amount of water required for its growth, and an increasing degree of aeration is found from the water line upward.

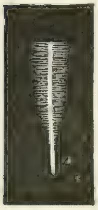
If the sphagnum cushion on a blueberry hummock is examined the whole mass will be found interlaced with the minute rootlets of the blueberry, far above the level of the underlying soil. The conditions of permanent moisture and thorough aeration found in these sphagnum cushions seem to be almost ideal for the development of blueberry roots.

It must not be assumed that the vigorous growth of blueberry roots in sphagnum is due to any high nutritive quality of the sphagnum itself. Such a conclusion would be erroneous. When set out in sphagnum and watered with tap water, blueberry plants remain healthy and develop a very large root system, but the stems do not grow as luxuriantly as when the plants are in a peat soil. From experiments with the growing of blueberries in sand watered with peat water it is known that such water furnishes the food materials necessary for vigorous growth. It is reasonable to conclude, therefore, that the chief nourishment of a blueberry plant growing on a pure sphagnum hummock comes from the bog water sucked up by the sphagnum and not from the sphagnum itself.

PECULIARITIES OF NUTRITION.

(13) THE SWAMP BLUEBERRY IS DEVOID OF ROOT HAIRS, THE MINUTE ORGANS THROUGH WHICH THE ORDINARY PLANTS OF AGRICULTURE ABSORB THEIR MOISTURE AND FOOD.

The structure of the rootlets of ordinary agricultural plants may be understood by reference to figures 11 to 13, which illustrate these organs as they occur in a wheat seedling germinated between layers of moist blotting paper. Attention is directed particularly to the root hairs. It will be observed that the wall of the root hair is very thin, appearing in optical section as a mere line with barely measurable thickness, even when highly magnified. Furthermore, the surface area of the root hairs is many times greater than that of the root itself. The chief function of these root hairs is to absorb for the use of the plant the soil moisture and the plant-food materials dissolved in it, a function which the root hairs are enabled to perform with great efficiency because of the two characteristics just mentioned—their large surface area and the thinness of their walls.



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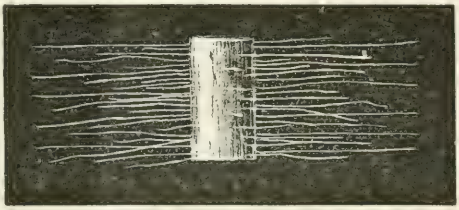

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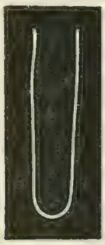

13.

FIG. 11.—Root of a wheat plant, showing the root hairs. (Natural size.)
FIG. 12.—Portion of a wheat root, with root hairs. (Enlarged 10 diameters.)
FIG. 13.—Tip of the root hair of a wheat plant. (Enlarged 1,000 diameters.)

The rootlets of the blueberry are remarkable in having no root hairs whatever, as may be seen by reference to figures 14 to 16. The walls of the superficial, or epidermal, cells of the rootlets are thick, measuring 0.00005 to 0.0001 of an inch (1.3 to 2.5 μ), while the walls of the root hairs of wheat are one-fourth to one-sixth as thick, so thin, in fact, that they could be measured only with difficulty even when enlarged 5,900 diameters. Notwithstanding the fact, therefore, that the blueberry roots are fine and numerous, their actual absorptive capacity would appear to be small, in consequence of the absence of root hairs.

It is found by a computation that a section of a blueberry rootlet having no root hairs presents about one-tenth the absorptive surface of an equal area of a wheat rootlet bearing root hairs, and the thickness of the surface membranes in the wheat is certainly not more than a quarter that in the blueberry. Furthermore, the blueberry rootlet grows only about 0.04 inch (1 mm.) a day under favorable conditions, while the wheat rootlet often grows twenty times as fast. In all this provision for rapid food absorption in the one plant and retarded absorption in the other we find a reason for the comparatively very slow rate of stem growth that characterizes the blueberry plant. The importance of slow root absorption and the danger to which these plants would be subjected if their roots absorbed water rapidly are discussed on page 50.

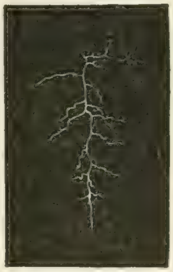

FIG. 14.—Root of a blueberry plant. (Natural size.)

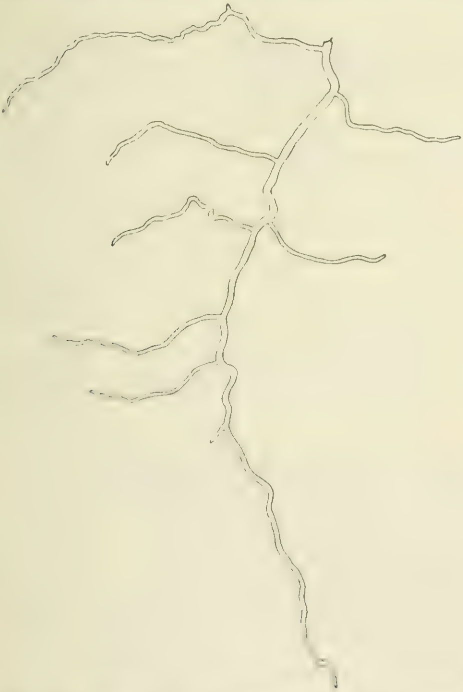

FIG. 15.—Root of a blueberry plant. (Enlarged 10 diameters.)

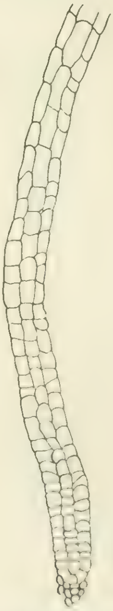

FIG. 16.—Blueberry rootlet (Enlarged 100 diameters.)

The young rootlets of the blueberry before they branch are exceedingly slender, varying from 0.002 to 0.003 of an inch (50 to 75 μ) in diameter. This makes them very susceptible to actual drying and they are easily killed by it. This characteristic has an important bearing on the treatment of these plants when in pots. The matter is discussed on pages 65 to 67.

(14) THE ROOTLETS OF HEALTHY PLANTS OF THE SWAMP BLUEBERRY ARE INHABITED BY A FUNGUS, OF THE SORT KNOWN TECHNICALLY AS AN ENDOTROPHIC MYCORRHIZA.[a]

As already stated, the ultimate rootlets of the blueberry are very fine, their diameter varying from 0.002 to 0.003 of an inch (50 to 75 μ). In rootlets of the smaller size about three rows of epidermal cells are visible in a lateral view, in the larger rootlets about five rows. In a newly grown rootlet not contaminated with soil particles these epidermal cells, and, indeed, all the underlying cells as well, are as transparent as glass, and were it not for the difficulties due to the refraction of light the examination of the contents of the cells would not be difficult. As a matter of fact the study of the contents of the live cells is difficult, their intelligent examination requiring the use of an oil immersion objective and microscopic enlargements of 1,000 to 1,500 diameters. The darkened window installation for a microscope, devised by Dr. N. A. Cobb, of the Bureau of Plant Industry, and used in his laboratory, has been found almost indispensable in this work.

Clean rootlets may be procured readily from active blueberry plants in the open spaces between half-rotted leaf blades, in clean sand, in live sphagnum, or at the outer surface of the ball of soil in earthen pots. Rootlets taken from live sphagnum are especially clean. They are conveniently studied when simply placed in water on a microscope slide under a thin cover glass held in place by a ring of paraffin.

Ordinarily the only thing visible in one of the live epidermal cells is the minute cell nucleus lying close to the cell wall. The protoplasmic membrane lining the cell is very thin and is invisible except where it is thickened to envelop the nucleus. The remainder of the cell is filled with the colorless cell sap. An examination with medium enlargements will show some of the cells faintly clouded in appearance. A higher power, such as is afforded by a 2-mm. oil immersion objective and a 12-mm. eyepiece, with proper illumination, will resolve the cloudiness into a mass of fungous threads, or hyphæ. These may be few, making only two or three irregular turns about the interior of the cell, as occasionally found, or they may be more numerous, even occupying the whole sap space, as shown in figure 17, in a dense knot of interwoven and irregular snakelike coils. These hyphæ are about 0.00006 to 0.00012 of an inch (1.5 to 3 μ) in diameter.

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[a] The spelling *mycorhiza* is also in good standing and is used in many German, English, and American botanical works.

On the outer surface of the cells containing these fungous threads others of similar or a little greater thickness may be observed. Sometimes they are transparent and their detection requires the same high power of the microscope as do those in the interior of the cells. Sometimes, however, these exterior threads have a pale-brown color and are then readily seen. Their surface is smooth, devoid of markings of any kind. Ordinarily the thread wanders loosely along the surface of the root giving off an occasional branch and having an occasional septum. Sometimes the threads and their branches may form an open network about the rootlet, but they never form a dense sheath of hyphæ such as is characteristic of the mycorrhiza of the oak.

The connection between the external and the internal hyphæ is not easy to see at a single observation, for the passage of the hyphæ through the cell wall is rarely caught in optical section, and even then a clear observation is usually rendered difficult because of refraction. A very clear case, however, was observed in a rootlet of laurel (*Kalmia latifolia*), a shrub which has a mycorrhizal fungus similar to that of the blueberry. A drawing of that specimen is shown in figure 18.

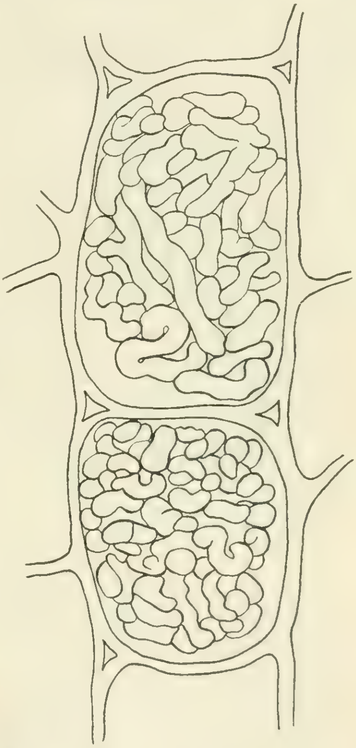

FIG. 17.—Mycorrhizal fungus of a blueberry plant densely crowded in two epidermal cells of the root. (Enlarged about 1,200 diameters.)

The passage of the fungus through the cell wall may frequently be observed in the blueberry by first focusing on the external hypha at a point where it appears to have a lateral hump or a very short branch, and then focusing slowly downward. In this way one passes from the external to the internal part of the fungus, having had some portion of the intervening hypha continuously in view. The hypha always appears much constricted at the point where it goes through the cell wall.

This fungus is of the type named by Frank in 1887 an endotrophic mycorrhiza to distinguish it from an ectotrophic mycorrhiza, such as occurs on the roots of oaks. In the latter type of mycorrhiza the hyphæ of the fungus form a dense sheath around the rootlet, completely shutting it off from direct contact with the surrounding soil. The loose hyphæ on the outside of the sheath resemble root hairs and it is supposed to be a part of their function to absorb soil moisture and transmit it to the oak rootlet just as root hairs do.

It has not yet been possible, for want of time, to study the life history of this mycorrhizal fungus of the blueberry. There is, however, a clew to its identity in the work of Miss Charlotte Ternetz, Ph. D., described on page 49.

The experiments thus far made do not warrant a supposition that any good peat soil requires inoculation with the mycorrhizal fungus before blueberry plants will grow well in it. The fungus appears either to be already in the soil or to accompany the seeds when they are sown in it.

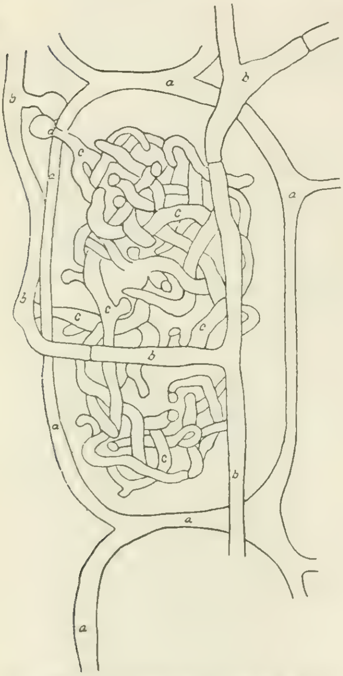

FIG. 18.—Mycorrhizal fungus of *Kalmia latifolia* in an epidermal cell of the root: *a*, Cell walls; *b*, external hyphæ of the mycorrhizal fungus; *c*, internal hyphæ; *d*, point of penetration of the cell wall by the mycorrhizal fungus. (Enlarged about 1,000 diameters.)

(15) THE MYCORRHIZAL FUNGUS OF THE SWAMP BLUEBERRY APPEARS TO HAVE NO INJURIOUS EFFECT, BUT RATHER A BENEFICIAL EFFECT, UPON THE BLUEBERRY PLANT.

The epidermal cells in which the mycorrhizal fungus occurs are not swollen nor distorted, nor do their contents collapse or show any of the other effects usually produced by pathological fungi. They appear to differ in no respect from other epidermal cells of the blueberry rootlets. In rapidly growing rootlets the fungus seems not to be able to keep pace with the rootlet itself and may not occur for a considerable distance back from the growing tip. The fungus-filled cells ordinarily are most numerous on certain small, short, and crooked lateral rootlets the growth of which is slow. When root growth of a vigorous plant is retarded or becomes even stagnated, the fungus may invade the epidermal cells to the very apex. Sometimes half the cells in such a rootlet are gorged with fungi, yet the delicate cell walls show no displacement or distortion. There is no indication whatever that the fungus causes any pathological disturbance or is in any way obnoxious to the plant. On the contrary, the uniformity with which it has been found to occur on healthy plants and its frequent absence or scarcity on sickly plants are facts suggestive of a beneficial influence. The nature of this beneficial influence is discussed on pages 48 to 50.

(16) THE ACID PEATY SOILS IN WHICH THE SWAMP BLUEBERRY THRIVES ARE DEFICIENT IN "AVAILABLE" NITROGEN, ALTHOUGH CONTAINING LARGE AMOUNTS OF "NONAVAILABLE" NITROGEN.

Ordinary agricultural plants absorb their nitrogen from the soil in the form of nitrates. Whether any are able to utilize directly other forms of nitrogen, particularly ammonia nitrogen, has been the subject of much experiment and of discussion by many authors. It is true in general, however, that the common plants of agriculture when their other food requirements are satisfactory make their growth in direct proportion to their ability to secure their nitrogen in the form of nitrates. For this reason the processes of agriculture are largely devoted to the securing and maintenance of conditions that will bring about the transformation of nonavailable nitrogen into nitrates. Soils in which this can not be done without great expense in proportion to their productiveness are generally considered poor.

The acid soils in which wild blueberries thrive are always looked upon as infertile in their natural state, and unless these soils are extensively manipulated cultivated plants do not do well in them. Whether or not a part of this infertility is due to the directly injurious effect of acid or other poisonous substances, it is known that the conditions existing in these soils are directly antagonistic to the formation of nitrates. (See p. 47.)

That kalmia peat, the soil found in these cultures to be most successful for blueberries, is deficient in nitrates, although containing an abundance of nitrogen in other forms, is shown by the following nitrogen determinations:

TOTAL NITROGEN IN KALMIA PEAT.

(Determinations made by Mr. T. C. Trescott.)

Sample.	Per cent.
1	0.95
2	1.46
3	1.18
4	1.15
5	1.40
6	1.12
Average of total nitrogen	1.21

NITROGEN IN KALMIA PEAT IN THE FORM OF NITRATES.

(Determinations made by Mr. Karl F. Kellerman.)

Sample.	Per cent.
7	0.0012
8	.0022
9	.0008
10	.0013
11	.0025
12	.0008
Average of nitrate nitrogen	.0015

(17) THE DEFICIENCY OF AVAILABLE NITROGEN IN THE ACID PEATY SOIL IN WHICH THE SWAMP BLUEBERRY GROWS BEST IS DUE TO THE INABILITY OF THE NITRIFYING BACTERIA TO THRIVE IN SUCH A SOIL BECAUSE OF ITS ACIDITY.

In order to understand the conditions antagonistic to nitrification which exist in good blueberry soils it is necessary first to discuss the source and transformation of nitrogen in ordinary soils.

The available nitrogen in the soil, such as is absorbed by an ordinary plant, is commonly derived, unless fertilizers have been applied, from the decomposition of the humus contained in the soil, and the humus is itself a product of the decomposition of plant and animal remains. These remains consist ordinarily and chiefly of the partially rotted leaves, stems, and roots of plants.

In the older agricultural literature the name humus was applied to a particular kind of soil which is more properly covered by the terms vegetable mold, leaf mold, and woods mold. (See p. 24.) Later the application of the word humus was restricted to that portion of a soil consisting of the plant and animal remains, in whatever stage of decomposition. The proper designation of these remains is, however, organic matter. In the sense just described the word humus is still frequently used, but not with correctness and precision. Humus, as now understood by agricultural chemists, represents a stage in the decomposition of organic matter in which the cellular structure has wholly disappeared and the original substance is or at some stage has been entirely dissolved.

Since it is often necessary to allude to organic matter in the earlier stage, as distinguished from organic matter as a whole, which includes the humus stage as well, the term cellular organic matter, or, more simply still, cellular matter, is suggested as a convenient designation. In cellular matter the cellular structure of the animals or plants still remains and may be detected either by the eye or by the microscope.

Humus, which is a complex mixture of diverse substances, does not ordinarily exist in the soil in a dissolved condition, but is usually combined with lime or magnesium. The resultant compounds, often indiscriminately blanketed under the names calcium and magnesium humate, are not soluble in water, but form a usually black precipitate, which gives a dark color to the soil.

To extract its humus a soil is first washed with dilute acid, by which the lime, magnesium, or other humus-precipitating substance is dissolved and leached away. The humus itself is then removed from the soil by long-continued washing with a weak solution, commonly 4 per cent, of ammonia. Upon the application of this treatment to kalmia peat an inky-black extract is secured. When this is evaporated to dryness the residue is a black substance which when scraped from the dish resembles coal dust or, even more closely, burned sugar. This substance is one of the forms of humus. It absorbs water readily, assuming the texture of thin jelly. It has a somewhat sooty odor and taste. It dissolves in water, the solution being acid in reaction. A liter of water in which had been dissolved a gram of humus extracted from kalmia peat showed when tested a 0.002 normal acidity. Such a solution is black unless viewed in a thin layer, and when diluted to 10,000 c. c. it has a brown color similar to that of ordinary cider vinegar. If lime is added to the solution the humus unites with it and is thrown down as a black precipitate, leaving the liquid clear. As stated in the preceding paragraph, it is in such a precipitated and neutral or alkaline form that humus ordinarily occurs. The characteristic brown color of the water in bogs indicates an acid condition, the presence of humus in solution, and the absence of soluble lime.

The process of decomposition by which cellular matter is transformed into humus, in which the cellular structure has entirely disappeared, is known as humification.

Humus contains nitrogen, but the nitrogen is not in the form of nitrates and therefore can not be assimilated by ordinary plants. The transformation of humus nitrogen into nitrates occurs during a further process of decomposition known as nitrification.

The nitrification of humus is brought about by certain bacteria which, growing in the humus-laden soil under suitable conditions, produce first ammonia, then nitrites, and then nitrates. In artificial cultures, in addition to proper conditions of temperature and moisture, and good aeration, these nitrifying bacteria require for vigorous growth a neutral or slightly alkaline medium. In a distinctly acid medium the nitrifying bacteria grow little or not at all.

In order to ascertain the degree of nitrification, if any, taking place in kalmia peat, a series of nitrification tests of this material was made by Mr. Karl F. Kellerman. These tests showed that neither in fresh peat nor in peat rotted for three months was nitrification in progress, but when the acidity of the peat was neutralized by the addition of lime nitrification began.

(18) FROM THE EVIDENCE AT HAND THE PRESUMPTION IS THAT THE MYCORRHIZAL FUNGUS OF THE SWAMP BLUEBERRY TRANSFORMS THE NONAVAILABLE NITROGEN OF PEATY SOILS INTO A FORM OF NITROGEN AVAILABLE FOR THE NOURISHMENT OF THE BLUEBERRY PLANT.

It is a well-established principle of plant physiology that (with the possible exception of a few bacteria) those plants which contain no chlorophyll, the green coloring matter of leaves, are unable to grow with mineral nutrients alone, since they are unable to manufacture their own carbohydrates. Plants without chlorophyll, including the fungi, are dependent for the fundamental part of their nourishment on the starch or other related carbohydrates originally elaborated from carbon dioxid and water by the chlorophyll-bearing plants. They also differ from the higher plants in being able to supply their nitrogen requirements directly from organic nitrogen compounds.

Fungi may be directly parasitic on a chlorophyll-bearing plant, as in the case of the mildew fungus of rose leaves, or they may grow on substances derived from chlorophyll-bearing plants, such as bread or jelly.

Fungi are particularly abundant in the decaying vegetable matter forming the leaf litter of a forest, even though this litter may be distinctly acid in its chemical reaction. They are known, indeed, to grow luxuriantly on vegetable remains containing no nitrates and of such acidity that nitrification, or the conversion of the humus nitrogen into nitrates by means of bacteria, can not take place.

That the mycorrhizal fungi, like other fungi, are able to extract nitrogenous food from the nonnitrified organic matter with which their external portions are in contact is a reasonable supposition. It is furthermore a reasonable supposition that the blueberry plant is able to absorb nitrogenous material from the internal portion of its mycorrhiza; for we know that the clover plant is able to absorb nitrogen under essentially the same conditions from the nitrogen-fixing bacteria growing in its root tubercles.

To establish by direct experiment the ability of the mycorrhizal fungus of the blueberry to act in accordance with the supposition outlined above, the fungus should be separated from the plant and grown by itself in suitable nutrient media. Preliminary trials were made to isolate the fungus, but without success, and a lack of time has prevented thus far the pursuit of that branch of the experiments.

(19) IT IS POSSIBLE THAT THE MYCORRHIZAL FUNGUS OF THE SWAMP BLUEBERRY TRANSFORMS THE FREE NITROGEN OF THE ATMOSPHERE INTO A FORM OF NITROGEN SUITED TO THE USE OF THE BLUEBERRY PLANT.

The fact of the fixation of atmospheric nitrogen by the bacteria inhabiting the root tubercles of clovers is now well known, and we are able to understand how the abundant nitrogen of the air, unavailable for the direct nutrition of ordinary plants, is made available for the use of leguminous crops.

It is not so generally known that there are in soils certain species of bacteria not connected with the roots of plants which also possess the faculty of taking up the nitrogen of the air and making it over into plant food. The extent of the distribution of these organisms and the amount of nitrogen fixation effected by them are not fully known, but the fact that such action does take place and that the bacteria causing it occur in many localities has been well established by the experiments of several investigators. The bacteria of this class most fully investigated are *Clostridium pasteurianum*, *Azotobacter chroococcum*, and several other species of this latter genus.

It has been shown also that certain fungi, such as *Penicillium glaucum*, possess this same power of assimilating atmospheric nitrogen.

After the writer had discovered the mycorrhizal fungus of the swamp blueberry in December, 1907, and while he was making observations on it, his attention was called to the work of Miss Charlotte Ternetz on the mycorrhizal fungi of certain related European plants. Miss Ternetz published in 1904 a paper[a] in which she made the preliminary announcement that a fungus isolated from the roots of the European cranberry (*Oxycoccus oxycoccus*) had developed pycnidia and that the mycelium produced from spores from these pycnidia when grown in a nitrogen-free nutritive solution, but with full access to air, showed upon analysis that it had assimilated free atmospheric nitrogen to the extent of 0.6 per cent of the dry weight of the mycelium. The fungus consumed only one-eighth as much dextrose in assimilating a given amount of nitrogen as was consumed by *Clostridium pasterrianum*. Similar but not identical fungi were isolated from other related plants.

In 1907, in a more detailed account of her investigations,[b] Miss Ternetz described, as new species of Phoma, five pycnidia-bearing fungi bred from the roots of the European cranberry (*Oxycoccus oxycoccus*), the marsh rosemary (*Andromeda polifolia*), two species of heather (*Erica tetralix* and *E. carnea*), and the mountain cranberry (*Vaccinium vitisidaea*). She was unable to demonstrate absolutely that these fungi were identical with the endotrophic mycorrhiza of the host plants because (1) it was extremely difficult to observe the fungous threads of the internal mycorrhiza grow through the cell wall of the rootlets into the culture medium without, and (2) because when she proposed to inoculate mycorrhiza-free seedlings of the host plants with spores from the pycnidia that formed in her cultures she was unable to grow any seedlings that were free from mycorrhiza.

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[a] Ternetz, Charlotte, Ph. D. Assimilation des atmosphärischen Stickstoffs durch einen torfbewohnenden Pilz. Berichte der Deutschen Botanischen Gesellschaft, vol. 22, 1904, pp. 267–274.

[b] Ternetz, Charlotte, Ph. D. Ueber die Assimilation des atmosphärischen Stickstoffes durch Pilze. Jahrbücher für Wissenschaftliche Botanik, vol. 44, 1907, pp. 353–408.

Notwithstanding the lack of an absolute demonstration that the nitrogen-fixing fungi grown by Miss Ternetz were identical with the mycorrhizal fungi of their hosts, it is regarded as quite possible that the mycorrhizal fungi that occur in perhaps all plants of the heather and blueberry families, including the swamp blueberry, are nitrogen fixers, and that the host plants absorb this nitrogen, giving in exchange, for the use of the fungus, sugar or some other carbohydrate.

The experiments thus far described in the present paper, and the accompanying discussions, appear to warrant the following theory of the method of nutrition of the swamp blueberry:

(*a*) The swamp blueberry grows in peaty soils which contain acid or other substances poisonous to plants.

(*b*) As a protection against the absorption of amounts of these poisons great enough to prove fatal, this plant, like many other bog and acid-soil plants, is devoid of root hairs and consequently has a restricted capacity for absorbing soil moisture. This low absorptive capacity is correlated with a low rate of transpiration. Many bog shrubs, although living with an abundant supply of moisture at their roots, have been recognized as showing adaptations for retarded transpiration similar to desert plants.

(*c*) The special danger to which the swamp blueberry is exposed by reason of its low transpiration and its corresponding reduced capacity for absorption is insufficient nutrition. The danger of nitrogen starvation is particularly great since these soils contain very little nitrates.

(*d*) Some bog plants similarly threatened with insufficient nutrition, such as the sundews (Drosera), the bladderworts (Utricularia), and the pitcher plants (Sarracenia), possess means of securing the requisite nitrogen by catching insects and digesting and absorbing their nutritive parts.

(*e*) In the swamp blueberry the required nitrogen is secured in a different way. The plant associates with itself a mycorrhizal fungus which is able to assimilate nitrogen from the surrounding organic matter, and perhaps from the atmosphere also, and to convey it into the plant without taking along with it a large amount of the poisonous soil moisture.

Whether this theory of the nutrition of the swamp blueberry is or is not substantiated in all its details by future investigation, it has afforded a useful basis for cultural experimentation, as will be evident from the results about to be described.

A METHOD OF POT CULTURE.

(20) SEEDS OF THE SWAMP BLUEBERRY SOWN IN AUGUST FROM FRESH BERRIES GERMINATE IN ABOUT FIVE WEEKS.

The experiments in the raising of blueberry seedlings have covered such a great diversity of soil mixtures, methods of potting, manner of watering, amount of shade, and day and night temperatures that an account of all of them is out of the question. The more important results of these experiments may be presented, however, in an account of the seedlings of 1908, the latest that have been grown for an entire year, with allusions to the experiments of other years whenever additionally useful. The parent plant of the seedlings of 1908 is described on page 80.

The method followed in germinating the seed was that developed by Mr. George W. Oliver, of the Bureau of Plant Industry, in 1902. All other experimenters, apparently, have considered it necessary to keep the seeds dormant by stratification or some equivalent means until late winter or early spring and then to give them the warmth necessary for germination. By Mr. Oliver's method, however, the seeds are sown in August, soon after the maturity of the berries; they begin to germinate in about five weeks, and by proper handling in the greenhouse they are robust plants by the beginning of summer instead of tiny seedlings.

Pursuing this method the detailed operations were as follows: The berries (Pl. VI, fig. 1) when fully matured and slightly fermented were mashed to a pulp and rubbed thoroughly under water. The juice and floating pulp were washed away, and the heavy seeds, which sank to the bottom, were taken out and their superficial moisture dried off by exposure to the air for a few hours. When thus prepared and placed in a closed bottle blueberry seeds will retain their vitality for several weeks, probably for several months.

From the 2 quarts of berries were secured 12.5 grams of dry seeds. The seeds numbered about 9,000 per gram, of which about three-fourths were small and contained no embryos. About 11 grams were used to raise seedlings, computed to contain about 25,000 germinable seeds. It furnished an abundant amount for seeding four ordinary gardener's flats, and from these over 1,000 seedlings were actually transplanted and as many more might easily have been utilized.

The mature seeds (Pl. VI, fig. 2) are roughly orbicular to narrowly oblong in outline, strongly flattened, with a deeply pitted seed coat. They vary in length from 0.04 to 0.06 of an inch (1 to 1.5 mm.).

The seeds were sown in shallow wooden flats 10 by 34 by 3 inches, inside measurement. After crocks had been placed over the drainage holes the bottom was covered to a depth of about an inch with kalmia peat in fibrous form to insure good drainage. Over this was placed the finely sifted soil of the seed bed, trodden down with the whole weight of the body, the total thickness of the soil and drainage being 2.5 inches.

The soil of the seed bed in this instance was a mixture of the following, each rubbed through a wire sieve with $\frac{1}{16}$-inch square openings:

Kalmia peat	8 parts by bulk.
Sand	2 parts by bulk.
Live sphagnum	2 parts by bulk.
Loam	1 part by bulk.

While this mixture gave good results, certain modifications in the direction of simplicity have been found equally satisfactory so far as growth is concerned, and more satisfactory with regard to the ease of transplanting. These changes involve the omission of the loam, which from other experiments is now regarded as never advantageous and sometimes actually injurious, and the omission of the sphagnum, which, although a good moisture-holding and aerating medium, appears to be superfluous in a peat and sand mixture. The sphagnum also interferes somewhat with the clean pricking out of the seedlings in the first transplanting. From experience with various other seedlings of blueberries a mixture of 2 parts of finely sifted kalmia peat to 1 part of sand is regarded as satisfactory and preferable. The peat should be well rotted and the sand clean and free from lime. This matter is more fully discussed on page 60.

After the seed bed had been prepared, as already described, the dry seeds were scattered upon it and covered with about an eighth of an inch of the same soil lightly sifted over it. The surface was then sprinkled with water from a sprinkling pot provided with a very fine rose.

So far as moisture is concerned the ideal condition of the seed bed is that the soil should be just damp enough so that it shall not become dry on the surface. The drying of this peat is indicated by a conspicuous color change, from dark brown to light brown. If exposed directly to an ordinary greenhouse atmosphere, the tendency of the seed-bed surface to become dry will necessitate frequent applications of water, and the bed will be in danger of repeated periods of sogginess. These conditions may be very much improved by covering the flat with panes of glass. An opening about an inch wide should be left at either end to permit the circulation of air over the seed bed. This ventilation will prevent the excessive accumulation of moisture in a stagnant atmosphere and will also prevent overheating on sunny days, both of which conditions are injurious to seedlings. A flat thus covered may not require watering for intervals of several days. The advantages of the glass covering are par-

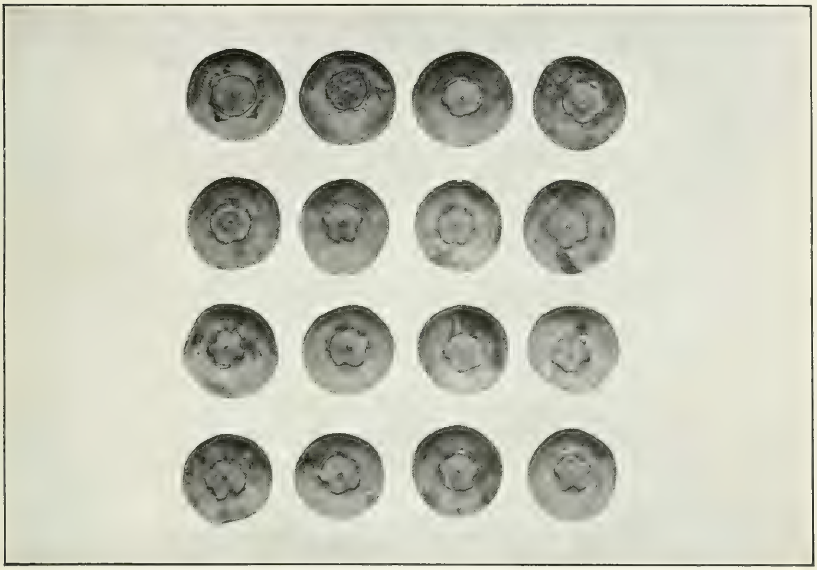


FIG. 1.—SWAMP BLUEBERRIES FROM THE PARENT BUSH OF THE SEEDLINGS OF 1908.

The berries were photographed after remaining nearly a year in formalin, and the illustration does not show their maximum size and plumpness. (Natural size.)

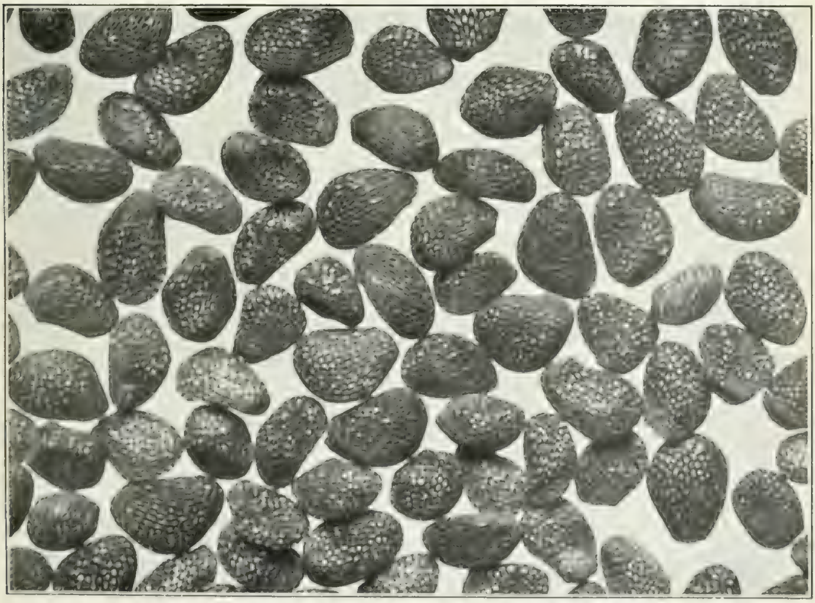


FIG. 2.—SEEDS OF THE SWAMP BLUEBERRY.

(Enlarged 10 diameters.)

ticularly evident when germination begins, for many of the seeds have been washed to the surface in the process of watering and have germinated without any soil covering. It may be several days before the root penetrates the soil, but the moisture maintained in the air underneath the glass keeps these naked seedlings from death by drying. After germination has progressed so far that a good stand of seedlings is assured the glass should be gradually removed.

The flats seeded on August 12, 1908, were kept in a greenhouse as cool as practicable and shaded from the sunlight. When started in winter, seed flats should be kept at a temperature not less than 50° to 60° F. at night and about 15 degrees higher in the daytime. Under such conditions sunlight during the whole day seems to benefit them.

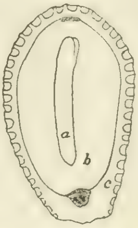


FIG. 19.—Section of a blueberry seed: *a*, Embryo; *b*, endosperm; *c*, outer seed coat. (Enlarged 18 diameters.)

Germination began on September 18, thirty-seven days after seeding, and continued for more than two months. In other seedings of this and the closely related blueberries known as *Vaccinium atrococcum* and *V. pallidum*, germination has begun in as short a period as twenty-five days. This slowness of germination might be considered merely a feature of the general sluggishness of growth in these plants. It is in fact, however, due to a much more specific cause. The food stored in the seed for the nourishment of the plantlet is not located in the cotyledons, as in the bean or pea, for example, but it lies in a mass called the endosperm, quite outside the embryo. (See fig. 19.) It requires several weeks for the minute embryo, feeding on the large mass of surrounding endosperm, to grow to sufficient size to burst open the seed coats. Until the embryo has attained such size it is physically impossible for the seed to germinate.

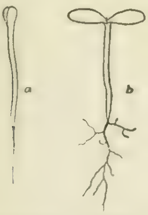


FIG. 20.—Blueberry seedlings in the cotyledon stage: *a*, Before the expansion of the cotyledons; *b*, at the beginning of the development of the first foliage leaf. (Enlarged 2 diameters.)

When the seedlings had straightened themselves out they were about 0.2 to 0.3 of an inch (5 to 8 mm.) high and the newly expanded cotyledons about 0.06 of an inch (1.5 mm.) long. (See fig. 20.) Within a few days the first foliage leaf began to appear between the cotyledons, and at the end of a month the plants were 0.4 to 0.6 of an inch (10 to 15 mm.) high, the erect unbranched stem bearing four or five foliage leaves, and the cotyledons having expanded to a length of 0.12 of an inch (3 mm.). (See fig. 21.)

Although the leaves of the parent plant had entire margins, the leaves of the young seedlings were invariably serrulate. It was only after the plants were several months old that any of the branches began to produce leaves with entire margins, and some of the seedlings from this parent give promise of permanently retaining the serrulate leaf character. (See p. 82.)

(21) THE SEEDLINGS ARE FIRST TRANSPLANTED AT THE AGE OF ABOUT SIX WEEKS, WHEN THEY ARE APPROACHING AN INCH IN HEIGHT.

On October 24 the first transplanting was done from the seed flats of 1908. A new flat was filled to a depth of 2 inches, trodden down hard, with the following mixture:

Kalmia peat, rotted for several months and rubbed through a quarter-inch sieve	8 parts by bulk.
Sand, coarse, washed	1 part by bulk.
Loam, clayey, finely sifted	1 part by bulk.

This soil mixture was used as the result of experience of the two preceding years. From a few experiments made in the winter of 1906–7 it had been found that a mixture of equal parts, by bulk, of peat, sand, and loam was decidedly superior to loam and manure or to sand, sphagnum, and loam. In the winter of 1907–8 it was found that the amount of sand and loam could be reduced with distinct advantage, and as a result of the experiments then made many of the cultures of 1908–9 were grown in the mixture described above (peat 8, sand 1, loam 1). The retention of the loam was due to an idea that this ingredient would furnish some necessary mineral nutrient not furnished by the peat. From an experiment made in the summer of 1909, however (p. 69), it was found that under the system of handling the pots described on page 67 large plants repotted in a peat soil with no loam whatever made a better growth than those potted in a peat containing a tenth part of loam. There is some reason, therefore, to suspect that loam, even in such a small quantity, may be slightly injurious, and more reason to suspect that it may be superfluous. Experiments intended to throw light on this question are now in progress.

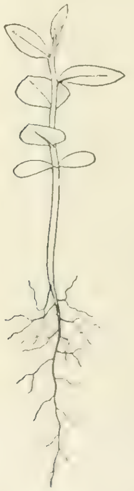


FIG. 21.—Blueberry seedling about six weeks old, with five foliage leaves. (Enlarged 2 diameters.)

In the soil of the flat, prepared as described above, 80 plants were set 2 inches apart. They were pricked out of the seed bed and set in the new soil by means of a small dibble. These plants were half to three-fourths of an inch high and had three to six true leaves.

It is believed that a spacing of 2.5 inches in the flat is better than 2 inches, as the plants have a little more room and the 2.5-inch square of earth is a very convenient size when the next transfer is made, into 4-inch pots.

From this time on during the winter the plants were kept in a cool greenhouse in which the night temperature was 55° to 60° F., and which was given a large amount of ventilation. The day temperature reached ordinarily 65° to 70° F. It was found that a house with a night temperature of 40° F. and a day temperature of 60° F. was too cold for such seedlings, as they made almost no growth at all. In a warm house, 65° to 70° at night and 80° to 90° F. in the daytime, blueberries grow fairly well, but they are much subject to injury by red spider (*Tetranychus bimaculatus*), and their new growth while sufficiently extensive does not appear so robust as in the 55° to 70° F. house.

For the first few days the newly transplanted seedlings were sheltered from direct sunlight. Later, however, they were given all the sunlight possible. It was found that during the winter, when well established in a suitable soil and under proper moisture conditions, the plants grew better when they received the fullest sunlight that the greenhouse afforded. This statement applies to the plants in all stages, whether in a seed bed or after the first transplanting or in larger pots.

In watering, the plants should be kept "on the dry side," as gardeners say. Water may advantageously be withheld until the surface of the soil is dry, but this condition should not be allowed to extend to a depth of more than about an eighth of an inch. Then a rather thorough watering should be given, which will carry moisture to the bottom of the soil, but not run through. Such a watering at infrequent intervals is preferable to frequent light sprinklings that moisten the surface only. Except for the brief period of percolation immediately after watering, the movement of water in the soil should be a capillary one, and from the bottom upward. Under such conditions, if the soil is of proper texture, good aeration is insured.

The shock of transplanting checks the growth of the seedlings for several days. This checking of growth may manifest itself in one or more of three ways: (*a*) The withering of the stem tip; (*b*) the "stagnation," or stoppage of expansion of the uppermost leaf rudiment; and (*c*) the purpling of the older leaves. As these phenomena when persistent have been much utilized in these experiments as warnings of the existence of conditions antagonistic to growth and as they may be of similar assistance to other experimenters, a description of them will be given.

The withering of the tip includes the uppermost leaf rudiment and the growing point of the stem inclosed within its folded base. The tissues turn brown and become dry, and the growth of that axis is terminated. The resumption of growth from such a stem, if it occurs, takes place through the formation and expansion of a bud in the axil of the leaf next below the withered one. This withering of the tip is readily distinguishable by its color from a partial blackening of the uppermost tender leaves which sometimes occurs, apparently a pathological disturbance of a temporary character and usually not affecting the growing point of the stem itself. The brown withering of the tip seldom takes place when the leaf rudiment involved in the withering is more than 0.1 inch (2.5 mm.) in length. When longer than that it usually keeps on expanding. This withering of the tips has been almost wholly prevented when the shock of transplanting was rendered as light as possible by suitable precautions, including (*a*) a soil in perfect condition for the nutrition of the plants, especially that in which the peat is well rotted (p. 61); (*b*) the transfer of the plants to their new bed without injury, especially without destroying any part of the roots; (*c*) the shading of the plants from direct sunlight for two weeks or more, until their new root growth is well established, and their subsequent gradual adjustment to full sunlight; and (*d*) the holding of the transplanted plants in a warmer, moister atmosphere, about 65° at night and 80° F. in the daytime. Whether or not this last condition had a real influence on the prevention of the tip withering is not definitely known.

The stagnation of the uppermost leaf rudiment does not attract the inexperienced observer's attention so readily as its withering. With a little experience, however, it is easily detected. Ordinarily the leaves of a growing stem follow each other at a rather close interval, so that by the time a half-grown leaf is ready to flatten out, from its boat-shaped folding in the younger stage, the succeeding leaf is commonly a third or more the length of the one that is flattening (fig. 22). When stagnation occurs, however, the uppermost leaf rudiment promptly stops growing, usually at a length of 0.04 inch (1 mm.) or less, while the young leaf next below it goes on flattening and growing to nearly its normal size. The end of the stem, therefore, shows a nearly full-grown flat leaf with a minute leaf rudiment at its base seldom more than a fifth and often not more than a tenth its own length.

The purpling of leaves, to which allusion has been made, does not refer to the reddish translucent appearance of the growing twig tips. That is the normal coloration in the blueberry, as it is, for example, in the rose. The purpling now under consideration occurs in the mature leaves, which are normally green, and is of a dark shade. It is commonly accompanied by a conspicuous reddening of the leaf veins. This purpling of the old leaves is evidence of a severe stoppage of growth and in these experiments has been observed to be caused by low temperature, about 40° F. or lower, or by lack of nutrition from any cause, or, apparently, by poisoning.

If the soil into which young blueberry seedlings are transplanted is suited to their growth, purpling of the old leaves seldom occurs, the evidence of the shock of transplanting being confined to the possible withering of a few of the stem tips and the temporary stagnation of others. In some transplantings no withering of tips occurs.

During the period of cessation of stem growth after transplanting, the plant is by no means idle, for the roots, as shown in glass-pot cultures, continue to make new growth, and when this has sufficiently progressed stem growth is resumed.

(22) WHEN ABOUT TEN WEEKS OLD AND NEARLY TWO INCHES IN HEIGHT THE SEEDLINGS BEGIN TO SEND OUT BASAL BRANCHES.

An important phase in the development of the seedlings of 1908 began on November 25, when one of the plants commenced to send out a branch from the axil of a cotyledon. At the expiration of another month 75 per cent of the plants in the flat had put out similar basal branches, and the remaining 25 per cent ultimately did the same.

These basal shoots are of the highest importance in the economy of the blueberry plant, for they soon far outstrip the first stem and become the principal seat of growth, until they themselves are overshadowed by later and still more vigorous basal shoots. The original stem of the seedling never develops into an ultimate main stem or trunk, but, as will be seen later (p. 58), stops growing while the plant is still young, and afterward dies. It is this habit of sending up basal shoots that makes the swamp blueberry a many-stemmed bush, not a miniature tree with a single trunk.

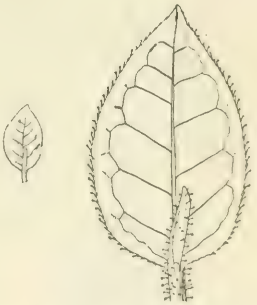


FIG. 22.—Normal tip of stem in a blueberry seedling. (Enlarged 4 diameters; the smaller figure natural size.)

The development of basal shoots began when the seedlings had about 12 leaves and were about 1.5 to 2 inches high. In this first basal branching the number of branches varied from 1 to 3. Out of 73 plants on which the branching was recorded 39 had 1 branch, 30 had 2 branches, and 4 had 3 branches. The branches occurred in the axils of the cotyledons or of one of the first four leaves. Of the 39 plants with 1 branch, 11 had the branch in the axil of a cotyledon, 17 in the axil of the first leaf, 8 the second, 2 the third, and 1 the fourth. Of the 30 plants with 2 branches, 11 had both branches in the axils of the cotyledons, 13 had neither branch so situated, and 6 had 1 branch from a cotyledon axil and 1 from a leaf axil. Of the 4 plants with 3 branches, 3 had all 3 branches in the axils of the cotyledons and the first leaf, 1 had a branch in the axil of a cotyledon and of the first and second leaf. Of the total 111 branches 46 were in the axil of one of the two cotyledons, an average of 23 to each, 36 in the axil of the first leaf, 20 the second, 7 the third, and 2 the fourth. In the order of the frequency of production of a basal shoot, therefore, the first leaf stands first, a cotyledon next, then the second, third, and fourth leaves, in order.

While the exact location of the basal branches appears to have no special significance, the number of the branches does, for the habit of producing two or more branches is a persistent one and such seedlings tend to produce diffuse plants with many and small stems and small stature, while the plants with the single-branch tendency are taller and have fewer and more robust stems. The differences in general appearance caused by the two types of branching are well illustrated in figures 24 and 25, from photographs of two seedlings of 1907 made at the age of 10 months.

(23) WHEN THE SEEDLINGS ARE ABOUT FOUR MONTHS OLD AND ABOUT THREE INCHES IN HEIGHT THE GROWTH OF THE ORIGINAL STEM TERMINATES.

On January 5, 1909, the growing tip on the original stem of one of the plants withered. At that time this stem was about 2.5 inches high, had 14 leaves, and had 2 vigorous basal shoots about an inch in length. This withering differed in one important respect from the withering due to shock, described on page 56. In that case it was an ordinary leaf rudiment that withered. In the present case the withering was foreshadowed by the development of a minute bract (fig. 23). This differed from the ordinary leaf rudiment in the absence of the glandular hairs characteristic of young leaves, and it remained small until the leaf next below it had become more than ten times as long. Then the bract withered and the growth of the original stem was permanently terminated. The same development went on in the other plants until at the end of a month 65 per cent and in two months 95 per cent of the plants had terminated the growth of their original stems.

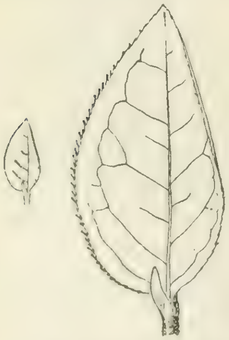


FIG. 23.—Bract and young leaf at the end of the original stem in a blueberry seedling. (Enlarged 4 diameters; the smaller figure natural size.)

In the individual plant the termination of growth on the original stem took place after the basal shoot or shoots had reached a stage of vigorous development. Out of fifty-nine normal cases observed prior to the second transplanting of the seedlings, the length of the new shoot, or when more than one the longest of them, at the time of termination of growth on the old stem varied from 0.4 of an inch to 5 inches, with an average of 1.8 inches. It would appear that the immediate cause of the termination of growth on the old stem is the diversion of food materials into the new vigorous growth.

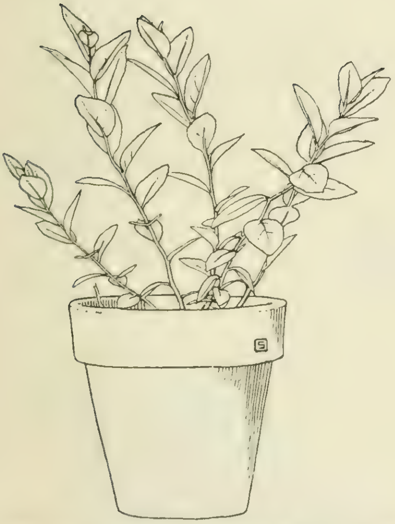


Fig. 24.—Blueberry seedling with diffuse type of branching. This will become a low, many-branched bush. (One-third natural size.)

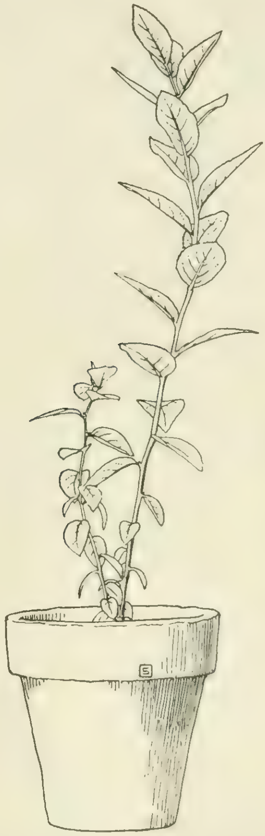


Fig. 25.—Blueberry seedling of the type with few branches. The branch is more than twice as tall as the original main stem. (One-third natural size.)

(24) WHEN THE PLANTS ARE ABOUT FIVE MONTHS OLD AND FOUR TO SIX INCHES IN HEIGHT THEY ARE POTTED IN FOUR-INCH POTS IN THE BEST PEAT OR PEAT MIXTURE.

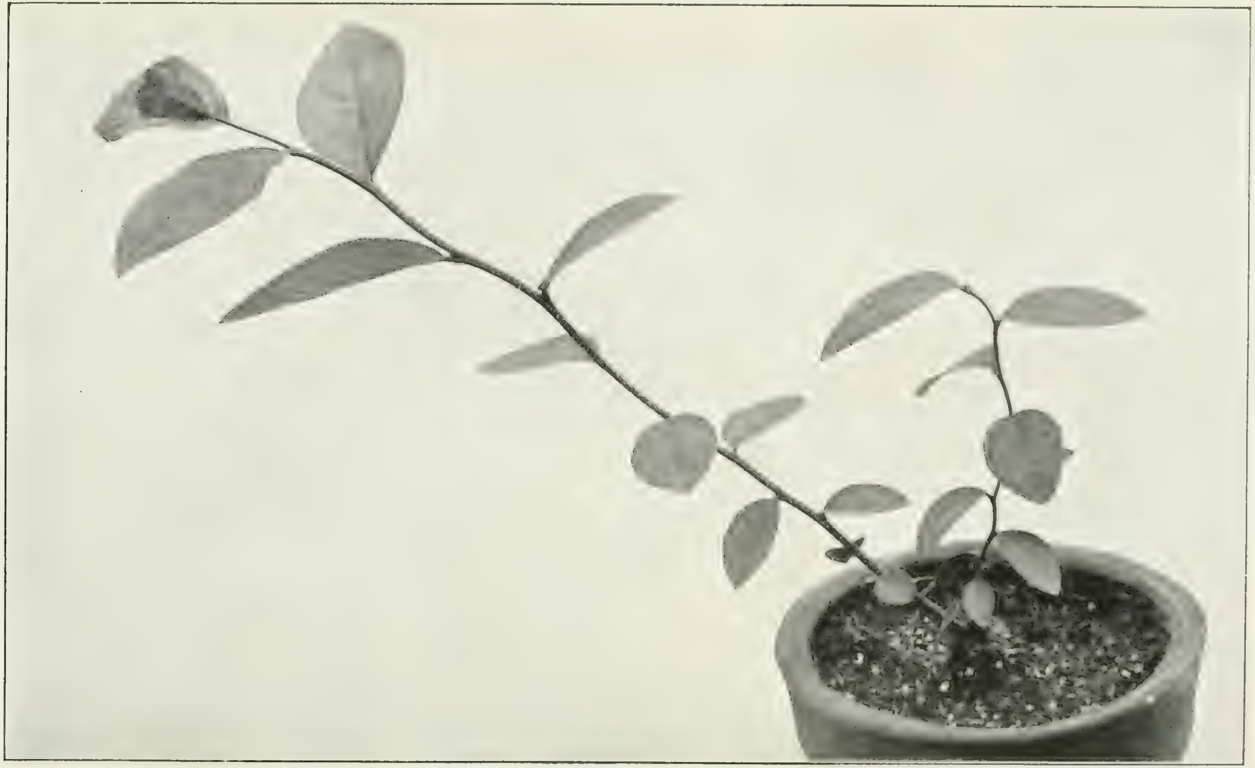
On February 17, when the plants were 4 to 6 inches high, they were transplanted into 4-inch pots in the same soil mixture as was used in the transplanting of October 21 (peat 8, sand 1, loam 1). As stated in the discussion of that transplanting, the plants would probably have done somewhat better without the loam. In addition to the crock over the drainage hole, a mass of fibrous kalmia peat was placed in the bottom of the pot, filling it, when pressed down, to the depth of an inch or more. After cutting the soil in the flats into rectangular cakes, the plants were lifted and transferred to the pots with the least possible disturbance of the roots.

Several experiments had been made earlier to ascertain whether at the first transplanting from the seed bed it is better to set the plants in flats or to put them in 2-inch pots, or thumb pots as they are more commonly called. It was found that when the plants in thumb pots were set on a greenhouse bench they tended to dry out so rapidly that it was impracticable to keep them in the right condition of moisture. They became so frequently too wet or too dry that their growth was interrupted and they were much inferior to the plants in the flats. Other plants in thumb pots (Pl. VII), plunged in either sand, peat, or sphagnum, made about the same growth as the plants in the flats, but showed no uniform advantage over them, either while they were in the thumb pots or after a second transplanting. The labor of transplanting and of maintaining uniform moisture is somewhat greater in the case of the potted plants. All things considered, in the original transplanting the use of flats is regarded as preferable to 2-inch pots.

It is desirable to consider at this time the exact qualities of the soils used in the potting mixtures. As already stated, it is regarded as preferable to omit the loam.

The sand should be free from lime, as most sand is, in fact. It should also be as clean as possible. If the only sand obtainable is mixed with clay, this should be removed by repeated washing in water.

The condition of the peat should also be carefully considered, as shown by the following experience during the progress of these experiments. From the seedlings of 1908 many series of transplantings were made on various days in October, November, and December. In the latter part of December it was noticed that while in some of the transplantings the seedlings were growing vigorously, other cultures were not doing well at all. Many of the tips were withered, over 25 per cent in some of the cultures; the rest became stagnated and dark purple, and remained so for nearly two months. All possible causes of the trouble having been eliminated except those due to the soil, the characteristics of the various soils used were considered with care. At this time the writer was possessed of the erroneous idea that lime in the minutest quantities was very injurious to the blueberry (p. 20), and consequently it was sus-



BLUEBERRY SEEDLING FOUR AND A HALF MONTHS OLD.

The original stem, erect in the illustration, has terminated its growth and is much exceeded by the vigorous basal shoot. (Natural size.)

pected that the sand was impure and contained lime. An examination of the sources of the different kinds of sand used showed that lime could not have caused the trouble. Finally, however, the various cultures were arranged by the dates of potting, and it was then found that the purpled plants had all been potted after a certain date, on which a new lot of peat had been received at the greenhouses. The peat in the earlier cultures had been received in June and at the time of the first transplantings had been rotting for four months at a warm summer temperature. The seedlings transplanted into this peat did not lose their tips, and growth was resumed almost immediately. The peat used after the middle of November was freshly gathered, and it was in this fresh peat that the seedlings suffered as already described. It should be stated here, however, that by the end of two months these seedlings, which meanwhile had been making good root growth, began to make rapid top growth also and later overtook their competitors.

Acidity tests of peat from the various cultures and in different stages of decomposition showed a remarkable correlation between the acidity of the peat and the behavior of the seedlings. In the fresh deleterious peat the acidity was excessive, varying from 0.03 to 0.046 normal. In the older peat in which the plants grew well the acidity was usually not in excess of 0.02 normal, in one case 0.024. Fresh peat rubbed through a quarter-inch sieve and showing an acidity of 0.034 normal had lessened its acidity to 0.02 normal after remaining in a moist well-aerated condition for three weeks in the warm air of a greenhouse. In view of these facts the conclusion was reached that the deleterious effect of fresh peat is due to its excessive acidity.

In the undisturbed peat of a kalmia thicket wild blueberry plants are often found growing luxuriantly. After this peat is stripped from the ground it becomes injurious, as has been shown, to blueberry plants that are potted in it, this injurious quality being correlated with an excessive acidity. The question arises, What causes this increase in acidity and in what particular part of the soil does it reside? It was at first suspected that the excessive acidity was located in the less decomposed upper layers of leaves which the roots of the blueberry plants in a wild state do not reach, but which, when the peat is rubbed through a sieve, go into the resulting mixture. The leaf layers to which reference is here made are not the uppermost, nearly dry layers a year or less old, for these are removed in gathering the peat, but the partially rotted layers one to two years old, such as those shown in Plate IV. An examination of such material showed that it was not excessively acid, but came well within the range of acidity beneficial to blueberry plants.

An acidity determination was then made of the roots in the peat. These are the roots, chiefly of oak and kalmia, that interlace the partly decomposed portions of the peat into mats or turfs. Their appearance in the upper part of these turfs is shown in Plate V, figure 2. Taking some of these turfs, freshly gathered, the soil was all shaken from them, leaving only the "fiber," consisting entirely of these fine live roots. This fiber was allowed to rot for a few days, and an acidity test was then made. It proved to be 0.07 normal, an acidity far in excess of that which had proved injurious to the blueberry seedlings. The excessive temporary acidity of freshly gathered kalmia-peat turf and its consequent temporary injuriousness to blueberry plants are therefore attributed to the diffusion through the peat of the acids originating in the roots killed in the process of gathering the turfs.

It should be added here that the acidity of the uppermost layer of undecomposed leaves a year or less old is very great, and that care should consequently be exercised to keep these out of the soil used. A test of dry, brown, newly fallen sugar-maple leaves showed an acidity of 0.22 normal, and a mixture of the leaves of various species of oak in a similar condition, 0.4. Incidentally, attention may be called to the presumable efficiency of a mulch of such leaves in maintaining, by means of its leachings, under the influence of the natural rainfall, the acidity of the underlying more fully decomposed layers, which without the addition of fresh organic matter would ultimately become alkaline. (See the account of an alkaline oak-leaf mold on p. 35.)

(25) BLUEBERRY PLANTS POTTED IN PEAT MAY BE MADE TO GROW MORE RAPIDLY IF THEY ARE WATERED OCCASIONALLY DURING THE GROWING SEASON WITH WATER FROM A MANURE PIT.

In the winter of 1907–8 pottings of seedling blueberries from seeds sown in August, 1907, were grown in various greenhouses of the Department. The most successful of these pottings consisted of 89 plants in a mixture of peat, sand, and loam in 3-inch pots. Two of these plants are illustrated in figures 24 and 25. It had been supposed that the superior growth of these plants was the result of specially favorable conditions of light, temperature, and watering, as indeed it was in part; but in the following winter, during an inquiry about certain details of the handling of this culture, the gardener in charge of the greenhouse in which the plants were grown admitted that during a portion of the spring, without consultation, he had given the pots an occasional watering with manure water. As manure when used with loam in the winter of 1906–7 had proved positively injurious to blueberry plants, its possible beneficial effect when used in conjunction with peat seemed worth testing further. In the spring of 1909, therefore, various cultures were watered with manure water once a week, the amount applied being the same as that given in an ordinary watering with tap water, about 50 c. c. for each 4-inch pot. The application was made to six cultures, containing altogether 156 plants, exactly comparable with a similar number of plants receiving no manure water. The applications were made in April and May and varied in number from five to eight.

In all six cultures the plants to which manure water had been applied made a more vigorous growth, temporarily at least, than those that received none.

Similar results were secured by the use of one-tenth cow manure, freshly rotted, in the peat mixture in which the plants were potted.

It was after the beneficial effect of this manuring had begun to show itself that a statement of similar results nearly a century old, in the culture of heaths, came to the writer's attention. It is contained in a book by William McNab entitled "A Treatise on the Propagation, Cultivation, and General Treatment of Cape Heaths," published in 1832. The original is now rare, but a reprint was published in 1908 in Notes from the Royal Botanic Garden, Edinburgh, volume 3, pages 351 to 374. McNab, who was the superintendent of the Edinburgh garden from 1810 to 1848, was undoubtedly the most intelligently successful grower of Cape heaths at the period of their greatest popularity. His treatise is original and practical and delightfully written. With reference to the manuring of heaths he states:

> I may mention that I have used a small quantity of manure in the foregoing compost with very good effect, about one-eighth part of cow dung. This should be well rotted before it is used. The way that I have always prepared this dung before using it is to take a barrow load of it and place it in thin layers between layers of peat earth, and after it has lain for some time, chop the whole up together, and turn it over at intervals till the dung disappears and the whole mass assumes the appearance of black peat earth and sand; and where this manure is applied about an equal quantity of sand should be added (that is, about one-eighth part of the whole) in addition to the sand that I have before recommended to be mixed up with the earth. This, I know, can be used with very good effect, but for all ordinary purposes I consider it quite unnecessary, as there is no difficulty in growing heaths very soon too large for the accommodation that is generally allotted for them, with the compost that I have mentioned without manure. I merely mention this because I know it is the opinion of some that heaths will not thrive with manure added to the peat earth in which they are grown.
>
> I know, however, that some heaths may be grown to a larger size, in the same space of time, with manure than without it; but, as I have already mentioned, I consider it quite unnecessary for all ordinary purposes, and any person who wishes to try its effects should do so very sparingly at first, till he is enabled to judge of the effect produced by it, as a little excess of manure is sure to injure the plants. Perhaps liquid manure might be used with very good effect for growing some kinds of heaths, but I am unable to give any particular directions in what proportion it should be used, as, from what trials I have made, I can not come to any certain conclusion. But this much I know, that whoever wishes to try it should do so at first with great caution, with quite as much as in using an excess of manure in its solid state.

McNab's conclusion that manure, while beneficial in small quantities, should be used with caution or not at all agrees with the conclusion reached from these blueberry experiments. On page 18 of this paper is described the disastrous results of the heavy manuring of blueberry plants, and in view of the fact that the blueberry makes satisfactory growth without manure and that we are not sufficiently informed of the exact conditions under which manure may become injurious, the use of even small amounts for blueberries is not now recommended.

A suggestion may be made, however, as to a possible reason for the injury of blueberry plants by manure. In the glass-pot experiment described on page 18, in which plants grown in a mixture containing half as much manure as peat made exceptionally good growth at first but soon died, the death of the plants was preceded by a rotting of the roots. Now, manure is alive with myriads of bacteria, while peat contains few. An examination of the two made by Mr. Karl F. Kellerman, from samples taken from the kalmia peat and the cow manure used in these experiments, showed 2,500 bacteria per plate in the manure and 70 to 150 in the rotted peat, each plate representing 0.0004 of a gram of material. The bacteria in the peat were chiefly of two species, while the manure contained many. It is a reasonable supposition that the rotting of the blueberry roots may have been caused or aided by the bacteria in the manure or by some of the fungi with which manure is also abundantly charged. In mixtures like those recommended by McNab, however, containing much peat and little manure, the injurious bacteria and fungi in the manure may have been killed or held in check by the acids that exist in the peat and keep such organisms in control. If experiments show this theory to be correct, the application of manure to blueberries may then be made intelligently.

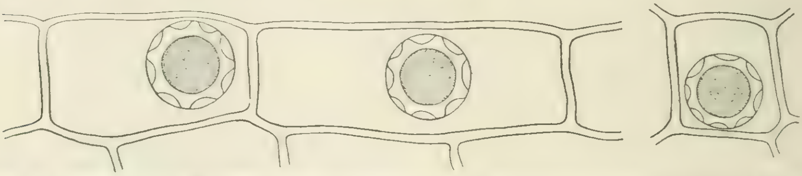


FIG. 26.—Spores of a supposedly injurious fungus in the epidermal cells of blueberry roots. (Enlarged 600 diameters.)

In this connection it may be well to call attention to a peculiar spore found in the roots of feeble blueberry plants grown in unfavorable soils, such as the limed peat and the clayey loam described on pages 23 and 24, and mixtures containing a large proportion of manure. In some of the epidermal cells of the rootlets were found large spherical bodies, as illustrated in figure 26. They usually occurred singly, though occasionally two and rarely three were found together in the same cell. They were 0.0007 to 0.0008 of an inch (18 to 20 μ) in diameter, and in optical section showed an outer ring and an inner ring, with 6, 7, 8, 9, or 10 introrse scallops in the hyaline zone between them, the space within the inner ring being granular. These are evidently spores with a very thick wall, marked with a few large pits or depressions, and granular contents in the cell cavity. In what appeared to be later stages of development of these spores, the diameter was slightly larger, the wall was thin, the pits had disappeared, and the granular contents had become organized into minute spherical bodies, apparently incipient swarm spores, about 0.0001 of an inch (2 μ) in diameter, approximately one-tenth the diameter of the spore itself. Several of these large, thin-walled spores had put out a short germination tube and lost their contents, the spore remaining entirely hyaline and empty.

It was thought at first that these might be the reproductive bodies of the mycorrhizal fungus of the blueberry, but a careful search failed to show any connection between the two. It was observed, however, that in the rootlets containing the spores the interior cells usually presented a diseased appearance, the whole rootlet sometimes showing a brown streak down its middle, due to the decomposition of the vessels and wood cells. The inquiry into the nature of the spores was not pursued further, but the conditions strongly suggested that the spores were those of a parasitic fungus occupying the interior of the roots and causing, or associated with, their death and decomposition. The spores themselves bear a strong resemblance to the resting spores of *Asterocystis radicis*, a parasitic fungus of the family Chytridiaceæ. This fungus occurs in Europe in the roots of various plants, particularly flax, in which it is the cause of a serious disease.[a]

If an explanation is sought for the injurious effect of lime on the growth of the blueberry, the observations already made indicate the propriety of a careful study of this large-spored fungus, with special reference to the effect of lime in stimulating its growth and the growth of the other organisms of decay associated with it.

(26) POTS CONTAINING BLUEBERRY PLANTS SHOULD BE PLUNGED IN SAND OR OTHER MATERIAL THAT WILL FURNISH CONSTANT MOISTURE AND GOOD AERATION.

Although the plunging of earthen pots nearly to the rim in some moisture-holding material, such as sand, sphagnum, or peat, had been practiced for various purposes in several of the earlier cultures, and had been found essential (as stated on p. 60) for 2-inch pot cultures if rapid and uniform growth was to be secured, nevertheless the importance of applying the same practice to larger pots was not appreciated until the best culture from the 1908 seedlings had remained almost stagnant in 4-inch pots for over a month. The condition of the plants was first attributed to an excess of acidity in some of the peat used for potting, and next to the necessity of a period of rest from active growth. Neither of these reasons, however, it was ascertained from observation of other cultures, could account except in part for the distressed condition that these plants finally reached.

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[a] Marchal, Emile. Recherches Biologiques sur une Chytridinée Parasite du Lin. Bulletin de l'Agriculture, Brussels, vol. 16, 1900, pp. 511–554.

When one of the plants was knocked out of its pot it was invariably found that a large part of the roots at the sides of the earth ball were dead. It was at the period of the year, April and May, when the advent of warm sunny days made the control of temperature in the greenhouse somewhat difficult, and this, together with the previous rapid growth of the plants and the consequent increase of their water consumption, had brought about considerable irregularity in the moisture content of the pots. The conclusion was reached that the walls of the pots had become dry on one or more occasions, and that this had killed the delicate roots that came in contact with them. The roots of the blueberry, as described on page 42, are exceedingly slender, the smallest being about two-thousandths of an inch in diameter. They are very quickly killed by drying.

On the basis of this conclusion the general practice of plunging blueberry pots was adopted. If the plants are to be exposed to a very warm, dry atmosphere the plunging should be done before any considerable quantity of roots has grown through the soil to the wall of the pot. It is probably still better to do the plunging immediately after the potting, for then uniform moisture conditions can be secured throughout the soil in the pot.

Besides the avoidance of injury to the plants by the drying of their roots, the practice of plunging has another marked advantage, the maintenance of a moderate but adequate and even optimum degree of moisture in the soil with infrequent waterings. A series of pots plunged in live sphagnum in a cool greenhouse during the winter of 1908-9 frequently went for a week at a time without requiring water and then most of the water was applied between instead of in the pots. The moisture evidently moves freely in or out through the wall of the pot, which is of course not glazed, and an excess or deficiency in any one place is soon adjusted.

Sand has been found a convenient and satisfactory plunging material. The surface of the sand should come to the same level as the soil in the pot, or a little above it. A little sand on the surface of the soil does no harm, and indeed is probably advantageous. When a single pot is to be plunged it may be done by placing it within another pot of 2 inches larger diameter, the space between the walls of the two pots being then filled with sand. (See Pl. XVIII.)

The practice of plunging has proved to be of the greatest importance in securing a large growth in potted blueberry plants, as will be appreciated from the description of the development made under such conditions out of doors in the summer of 1909. (See p. 68.) In that description special attention is drawn to the superior conditions of aeration in plunged pots.

(27) PLANTS OF THE SWAMP BLUEBERRY SOMETIMES LAY DOWN FLOWERING BUDS AT THE AGE OF SEVEN MONTHS.

The laying down of flowering buds is discussed in detail on pages 71 to 73, where a description is given of the general occurrence of this phenomenon in vigorous plants one year old. The first flowering buds, however, appeared much earlier. They were observed on April 8, 1909, on plants which were 10 days less than 7 months old. At the end of the 7 months 24 plants out of 258, which constituted seven of the most advanced cultures from the seedlings of 1908, had laid down flowering buds. A small percentage of the seedlings of 1907 had also laid down flowering buds at about the same age. The phenomenon may therefore be regarded as not rare in vigorous plants of this age.

These flowering buds, which contain the rudiments of about 7 to 12 flowers each, are not adapted to development into clusters of flowers until they have been subjected to a period of cold. Most of the buds, therefore, forming just as warm weather was approaching, withered and dried on the bushes. A few flowered in 1908 and in 1909, and in this latter year one plant bore ripe fruit on August 25, at the age of a little more than 11 months.

(28) IN THE SPRING AFTER THE DANGER OF FROST WAS PAST THE PLANTS WERE REPOTTED AND PLACED OUT OF DOORS, IN HALF SHADE, PLUNGED IN SAND.

On May 19 to 22, 1909, the seedlings of 1908 were repotted in 6-inch pots, in a mixture in most cases of peat 8, sand 1, and loam 1, and placed outdoors. The plants in the principal cultures had at this time an average height of about 9 inches, with a maximum of 15 inches. The pots were plunged in sand. They were in a situation where they were exposed to sunlight from about 8 o'clock in the morning to 5 o'clock in the afternoon, and to protect them from too great heat they were partially sheltered by a slat shade. The slats were 2 inches wide, with 2-inch openings between. As the sun struck the slats somewhat diagonally and they were half an inch thick, the plants when covered by the shades received a little less than half sunlight. On clear days the shades were kept over the plants from 9 o'clock to 4 o'clock. At other hours and on cloudy days the shades were removed. On August 25 the time of shading was shortened to the period between 10 and 3 o'clock, and after September 12 the shades were left off altogether.

The plants were watered with a swift spray from a hose, the water being applied only when necessary to keep the soil from actually drying out. The sand between the pots was seldom allowed to become dry to the depth of more than half an inch. A sand mulch of about a quarter of an inch on the top of the soil in the pot was found useful in preventing the rapid drying of the soil by direct evaporation.

(29) BY THE USE OF THE CULTURAL METHODS ALREADY DESCRIBED, SEEDLINGS OF THE SWAMP BLUEBERRY HAVE BEEN GROWN INTO ROBUST PLANTS OF A MAXIMUM HEIGHT OF TWENTY-SEVEN INCHES AT TWELVE MONTHS FROM GERMINATION.

The growth of the plants out of doors during the summer was remarkably vigorous. Hitherto experimenters with seedling blueberries have been able to produce only comparatively small plants at the end of the first season, as shown by the following citation from a publication of the best-known experimenter:[a]

> The blueberry makes much less growth the first two years from seed than the huckleberry, but grows faster afterward. The third year I have had them make a growth of 6 to 8 inches. The low blueberry and huckleberry begin to bear at 3 or 4 years, while the high-bush blueberry requires 4 to 6 years. From 1 to 3 inches growth the first year is about all you can expect.

Under the system of treatment described in the present bulletin seedlings have been grown to a height of 27 inches at twelve months from germination. Out of the seedlings of 1908, 250 were carried through to the close of the season of 1909 in 6-inch pots. Of these, 15 were stunted plants. The remaining 235 had an average height at the end of the season of exactly 18 inches. The larger stems were often a quarter of an inch in thickness, and the main trunk, half submerged in the ground, sometimes reached a diameter of half an inch. The general appearance of these plants is shown in Plate VIII.

The principal features of cultural treatment which have contributed to this development are (*a*) the autumn germination of the seeds, (*b*) the use of suitable acid soils, (*c*) the plunging of the pots, and (*d*) the partial shading of the plants during the heat of summer, the application of these cultural methods having been guided throughout by the discovery of the existence of a mycorrhizal fungus in these plants and its treatment as essential to their nutrition. The system of germination and the character of the soils used have already been described in detail. The exact effects of the plunging and the shading remain to be considered.

It has already been shown (p. 66) that when a plant is not plunged, the minute rootlets that lie against the sides of the pot

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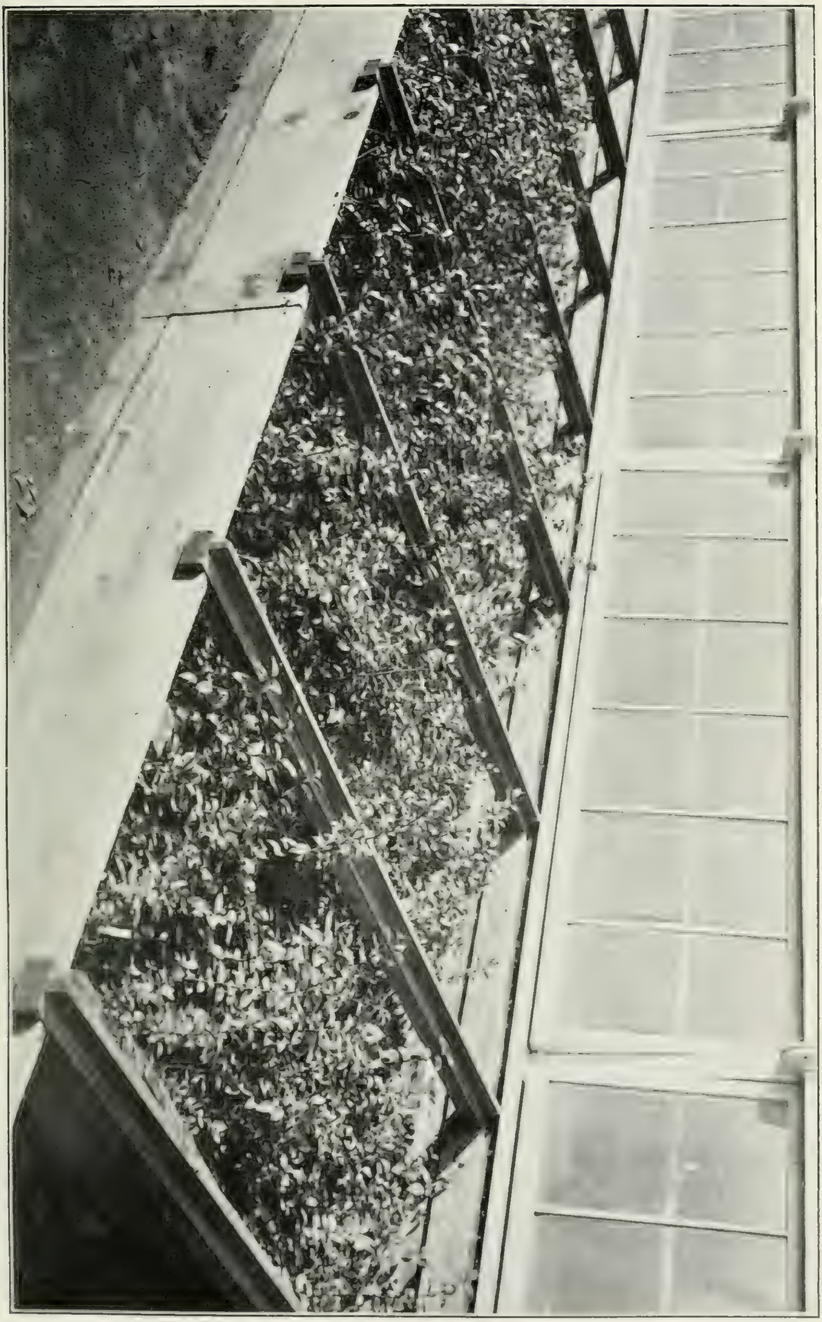
[a] Dawson, Jackson. Cultivator and Country Gentleman, vol. 50, 1885, p. 660.



COLD FRAMES CONTAINING ONE-YEAR-OLD BLUEBERRY SEEDLINGS.

are very liable to death from dryness. When the pot is plunged in sand and the sand is kept moist these rootlets can not die from drought. They keep on growing until, in the case of vigorous plants, when the earth ball is knocked from the pot, the soil can not be seen because of the dense mat of live roots that line the pot. The same thick mass of live roots was developed in a series of 1907 seedlings carried over the winter of 1908–9 in the greenhouse in pots plunged in sphagnum. When the pot is surrounded by the moist plunging material these roots continue to luxuriate for months longer than they otherwise would. They evidently find the aeration conditions, as well as the moisture conditions, at the wall of the pot very satisfactory, for the development of roots there is far greater than within the ball itself.

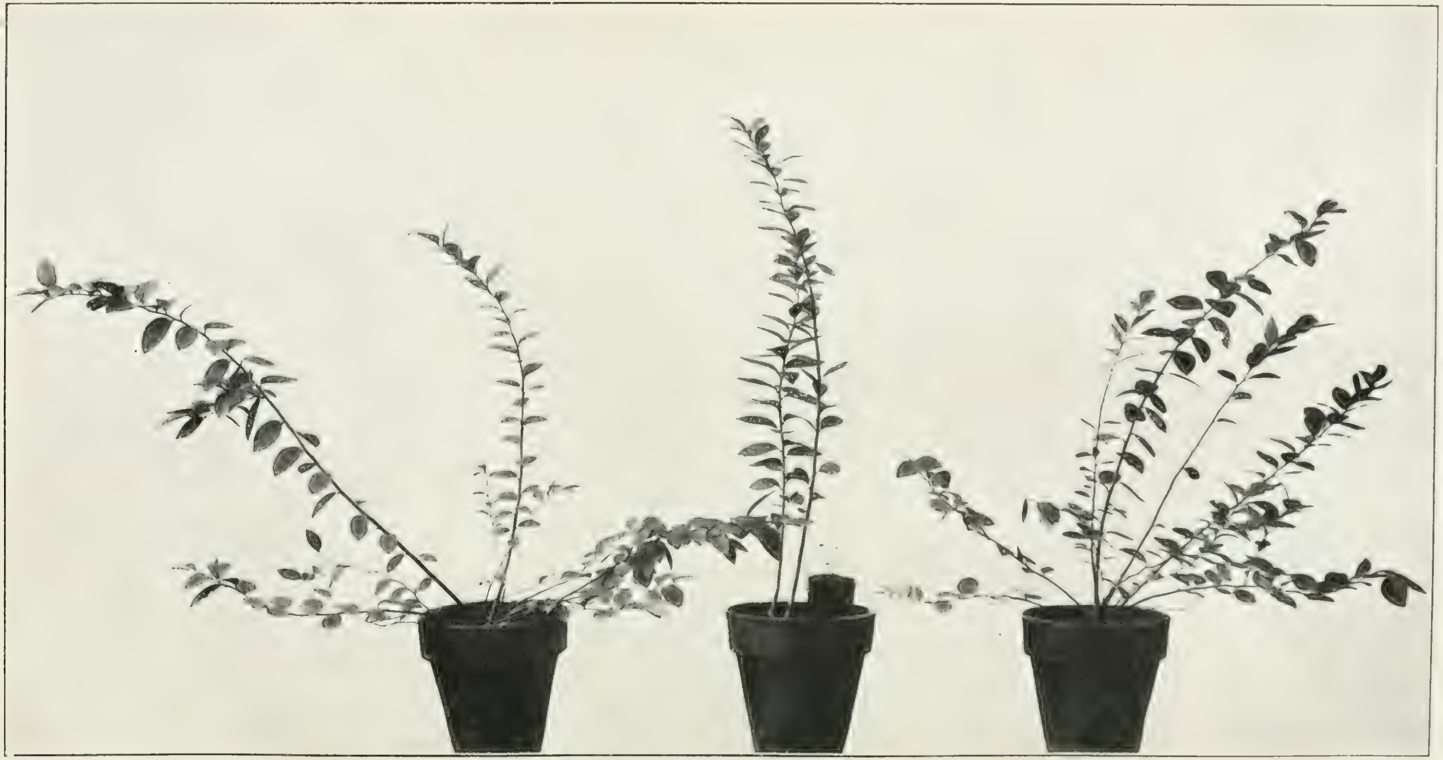
The highly efficient aeration at the wall of plunged pots may explain one use of soils in which the results of the present investigations do not agree with the practice of the old heath growers. In one culture of 25 plants the soil used in the first potting was pure rotted kalmia peat rubbed through a quarter-inch screen. This first potting, in 4-inch pots, was done on March 20, 1909. The repotting, in 6-inch pots, was done on May 22, 1909, in the same kind of soil, pure coarsely sifted kalmia peat. These plants grew to be the largest of any of the seedlings of 1908, their average height at the close of the season being 20.5 inches. The three plants shown in Plate IX, all over 24 inches in height and one of them 27 inches, were from this culture.

The use of pure peat was not advocated by the old heath growers. McNab recommended a mixture of 4 or 5 parts of peat, by bulk, to 1 of sand, and an even larger proportion of sand, 2 parts out of 5, has been recommended by Dawson for blueberries. When the pots are not plunged and do not therefore have the advantage of the superb aeration conditions found at the wall of the pot when surrounded by moist sand, it is probable that the presence of considerable sand in the soil is necessary to secure adequate aeration of the interior of the earth ball, for unless the pot is plunged most of the rootlets that lie against the sides of the pot will be killed and the plant must rely for its chief nourishment on the roots in the interior of the ball.

That the necessity for interior aeration in the pots is great in the case of heaths, if the plants are not plunged or are not frequently repotted, is shown by a peculiar and interesting cultural practice long tried and highly recommended by McNab. This practice is the distribution of broken crocks or pieces of sandstone through the soil at the time of repotting. He found by experience that the practice was highly advantageous to the plants, and although he did not directly explain his success in such a way, there is little doubt that his method, which may be regarded as a substitute for plunging, was advantageous because it gave large aeration surfaces about the stones in the interior of the earth ball and provided a place there for a large development of roots which could not take place at the wall of the pot. McNab's description of his method of repotting is as follows:

> In shifting heaths I never reduce the old ball of earth more than by rubbing the sides and bottom with the hand, so as to loosen the outside fibers a little. I have often shifted heaths twice, and even three times, in the course of the spring and summer, with the greatest success. It is, however, quite unnecessary to shift a heath until the young fibers have come through the fresh earth given to it at its previous shifting, and begun to extend themselves round the inner edge of the pot or tub; but as soon as this takes place, they may then be shifted with advantage. This frequent shifting, however, is quite unnecessary, unless it be to encourage a favorite specimen; for in all ordinary cases, particularly when the plant is large, I consider one good shifting in two or three years quite sufficient. * * *
>
> Besides the compost and draining which I have already mentioned, when I begin to shift heaths I have always at hand a quantity of coarse, soft freestone, broken into pieces, from an inch to 4 or 5 inches in diameter. Of these I always introduce a quantity among the fresh earth as it is put into the pot or tub, round the old ball of earth about the plant, and press them well down among fresh earth as it is put in. This I consider of great advantage to all sorts of heaths, but more particularly so to those that may have been shifted into a much larger pot or tub at once than what it had been grown in before, or in what I would call biennial or triennial shifting. These pieces of stone may be put in as large as the opening will admit between the old ball and the edge of the pot. In some of our largest tubs this opening is full 4 inches wide, and where much earth is required to be put in the bottom over the draining before the plant is put in, a quantity of these stones should be mixed with the earth also. I likewise use occasionally large pieces of soft burnt broken pots, put among the earth in the same way as the stones; but I prefer stones when I can procure them soft and free of iron. The quantity of stones which I introduce along with a large-sized heath at shifting, will, in most cases, if broken down into sand, and added to the sand previously in the soil, form about one-third part of the whole mass. When stones are introduced among the earth in the way I have recommended, heaths will never suffer so much in the summer from occasional neglect to water them as they would do if the stones were not introduced, because these stones retain the moisture longer than the earth, and in the winter they allow a freer circulation of any superabundant moisture which may be given through the mass.

The effect of the half shade used over the blueberries during the summer of 1909 was to make the growth of the plants continuous instead of confining it to a brief period in the early part of the season. In a wild state the twigs of blueberry plants stop growing in early summer, the stoppage being indicated by the withering of the uppermost leaf rudiment. The less vigorous twigs stop first, the more vigorous ones next, and the shoots last. Stoppage of growth is hastened by hot dry weather and is deferred by cloudy humid weather. In the latitude of Washington stoppage of ordinary twig growth in wild plants of *Vaccinium atrococcum* begins in May and is usually



LARGE ONE-YEAR-OLD SEEDLINGS OF THE SWAMP BLUEBERRY.

All three plants, grown in pure kalmia peat, are over 24 inches high, the one at the left 27 inches. The middle plant has been pruned. Standing on the middle pot is a small glass pot containing a seedling of the same age as the others but grown in a rich garden soil. (One-eighth natural size.)

completed, except on vigorous shoots, in June. In some of the cultivated plants which were not shaded growth was similarly stopped by the advent of hot weather. In the plants under the slat shades, however, vigorous stems did not wither their tips until their normal growth had run its course, and as new shoots were continually starting there was no general stoppage of growth until September, and many of the plants continued to grow throughout that month.

The shade was not great enough to "draw" the plants; that is, to make their growth spindling through a stretching up for light. It was merely sufficient to prevent excessive heat and destructive transpiration.

(30) THE FLOWERING BUDS OF THE BLUEBERRY ARE PRODUCED BY THE TRANSFORMATION OF DORMANT LEAF BUDS IN THE LATTER PART OF THE SEASON.

The flowers and leaves of the swamp blueberry are produced in the spring from separate buds, and these buds are formed in the preceding year. The two kinds of buds are conspicuously different, as may be seen by the accompanying illustration. (Pl. X, fig. 1.) The leaf buds occupy the lower part of the twig. They are small, conical, about 0.08 to 0.12 of an inch (2 to 3 mm.) long, with 2 to 4 external scales about equaling each other in length and each ending in a sharp point. The points only of the interior scales, which are of similar length, are visible. When a leaf bud develops in the spring it produces a leafy twig.

The flowering buds are borne along the upper part of the twig. They are fat, ovoid structures, commonly 0.15 to 0.3 of an inch (3.5 to 7 mm.) long, several times larger than the leaf buds. They show ordinarily 10 to 15 external, broad, overlapping scales. Each flowering bud contains the rudiments of a raceme of usually 7 to 12 flowers, the bud of each of these flowers lying in the axil of a bract and bearing two bractlets below the middle of its short pedicel. When a flowering bud develops it produces a raceme of flowers, but no accompanying twig or leaves.

Leaf buds are always axillary and flowering buds almost always so. The bud at the summit of a twig is in reality situated in the axil of the uppermost leaf, except in the rare cases in which the twig tip does not wither when it stops its growth. In such cases a true terminal bud is formed, surrounded by a group of lateral buds in the axils of bracts. So far as observed these buds are always flowering buds and are produced on the ends of vigorous shoots.

The manner in which the plants lay down their flowering buds, through the transformation of leaf buds, is very interesting, and it may prove to have a bearing of some importance on the method and time of pruning the bushes. The form of the leaf buds has already been described. They appear singly in the axils of the leaves almost as soon as the leaf is fully developed. After a few weeks the external scales of the bud turn brown and the bud then goes into a condition of dormancy, unless it is forced into growth through an injury to the twig or some other unusual circumstance. In most of the buds this dormant condition continues through the summer, fall, and winter. If the plant is in condition to lay down flowering buds, however, a new sort of activity appears in the late summer or autumn. One or more of the leaf buds near the end of a twig start to grow. The two brown scales are spread apart, new green scales appear between them, and a large, fat, flowering bud is formed. The bud does not, however, continue its growth at this time, but its green new scales turn brown and the condition of dormancy is again resumed before cold weather comes on.

The flowering buds thus develop out of buds which are in no way distinguishable from leaf buds. They are, in fact, leaf buds until their transformation takes place, and except for such transformation they would remain leaf buds. Furthermore, it has been found experimentally that after the formation of flowering buds has been completed, leaf buds still lower on the twig can be forced by suitable treatment to transform themselves into flowering buds. Such an experiment was made, as follows:

On August 24, 1909, at Lanham, Md., a vigorous bush of *Vaccinium atrococcum* was selected, which had already laid down its flowering buds for the succeeding year. Two branches of nearly equal size, about 16 inches long, one with 14 twigs and 53 flowering buds, the other with 16 twigs and 48 flowering buds, were chosen for the experiment. On the branch containing the 48 flowering buds each twig was cut off at a point between its lowermost flowering bud and its uppermost leaf bud, with the object of ascertaining whether any of the leaf buds on the stub of the twig would transform themselves into flowering buds. The other branch was left unpruned as a check, to show whether the normal laying down of flower buds had in reality been completed on August 24. On October 1, 1909, the two twigs were again examined. The pruned branch had laid down 31 new flowering buds, which in all cases were the transformed upper leaf buds on the stubs of the twigs. On the check branch only 1 new flowering bud had been laid down.

The best method of pruning the swamp blueberry is yet to be devised, but if a superficial pruning, like that of a hedge, proves to be a good method of stimulating vigorous growth, it is evident from this experiment that the most advantageous time to do the pruning, if a crop is to be secured the next year, is after the berries are gathered and about the time when the bush is forming its next year's flowering buds. It will then lay down new flowering buds on the cut stubs. If the pruning were done in late autumn, in the winter,

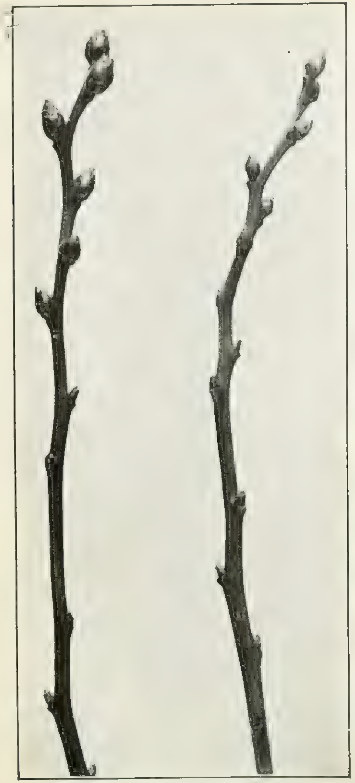


FIG. 1.—FLOWERING BUDS AND LEAF BUDS ON BLUEBERRY TWIGS.

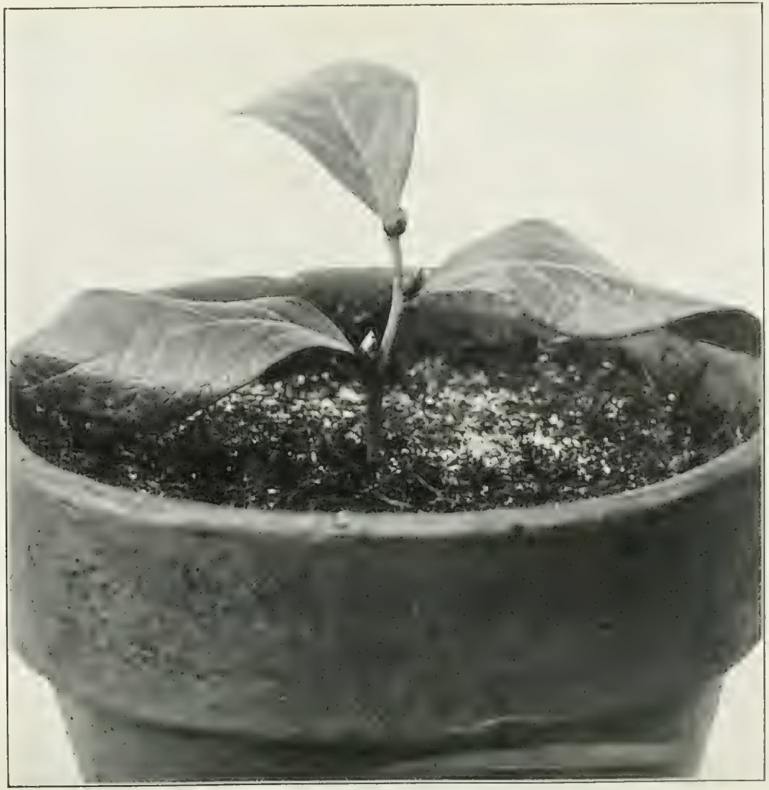


FIG. 2.—FLOWERING BUDS ON A BLUEBERRY CUTTING.

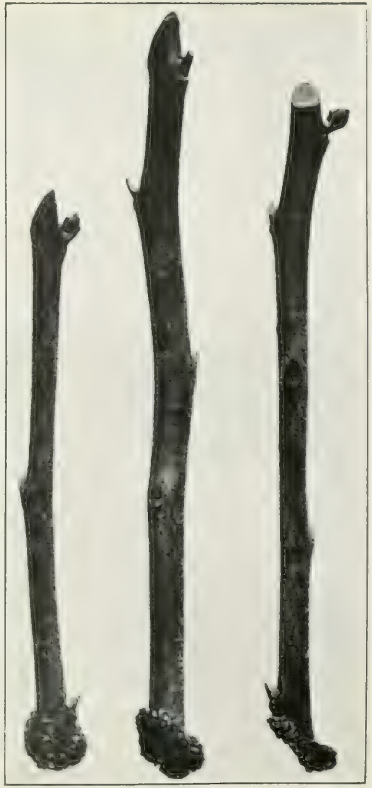


FIG. 3.—FLOWERING BUDS ON BLUEBERRY CUTTINGS.

Each twig in figure 1 shows six flowering buds. The twigs were photographed in March from plants that were 1 year old when the buds were laid down. The middle cutting in figure 3 bears only leaf buds; the two lateral ones have each transformed their uppermost leaf bud into a flowering bud. (All natural size.)

or in the spring, no new flowering buds would be formed to replace those removed by the pruning.

The time of laying down flowering buds seems to be correlated with the length of the growing season. About Washington *Vaccinium atrococcum* begins to form its flowering buds in the latter part of August, one to two months after its berries are matured. In *Vaccinium pallidum*, on the high mountain summits of North Carolina, where the growing season is short, the transformation of leaf buds into flowering buds begins as early as the last week in July while some of the berries are still green. In the cultivated plants at Washington the formation of flowering buds did not begin in 1909 until September, and it continued on some plants until cold weather stopped their growth.

The laying down of flowering buds appears to be a phenomenon local within the twig. Cuttings of the swamp blueberry made in New Hampshire on July 9, 1909, transformed their leaf buds into flowering buds in the cutting bed after reaching Washington, as shown in Plate X, figure 2, but whether the transformation in this case was made before or after the cutting had rooted was not observed. In another case, however, that of cuttings made in New Hampshire September 11, 1909, from long late shoots bearing only leaf buds, the transformation into flowering buds began to occur in the cutting bed October 12 and was completed before any roots had formed. (See Pl. X, fig. 3.)

(31) AT THE END OF THEIR FIRST YEAR SEVENTY PER CENT OF THE BLUEBERRY PLANTS HAD LAID DOWN FLOWERING BUDS FOR THE NEXT SPRING'S BLOSSOMING.

At the end of the season of 1909, 177, or 70 per cent, of the 250 seedlings of 1908 that had been put in 6-inch pots had developed flowering buds. In Plate XI is shown one of these seedlings, photographed on November 2, 1909, which had laid down 42 flowering buds. One plant produced 58 flowering buds. At the end of the preceding season, 1908, at least 25 per cent of the seedlings of 1907 that were still kept in pots had produced flowering buds. Therefore, notwithstanding the statements of earlier experimenters that the seedlings of this species do not fruit until they are several years old (p. 68), it is regarded as established that under the culture system worked out by these experiments a substantial percentage will lay down flowering buds at the end of the first year and will bear fruit the second year.

Attention has already been called (p. 67) to the occasional laying down of flowering buds when the seedlings were only 7 months old, followed rarely by flowering and fruiting at the age of less than a year.

(32) Plants of the swamp blueberry are exceedingly hardy and pass the winter in good condition outdoors when the soil is covered merely with an oak-leaf mulch, but when not exposed to outdoor conditions they do not begin their growth in spring in a normal manner.

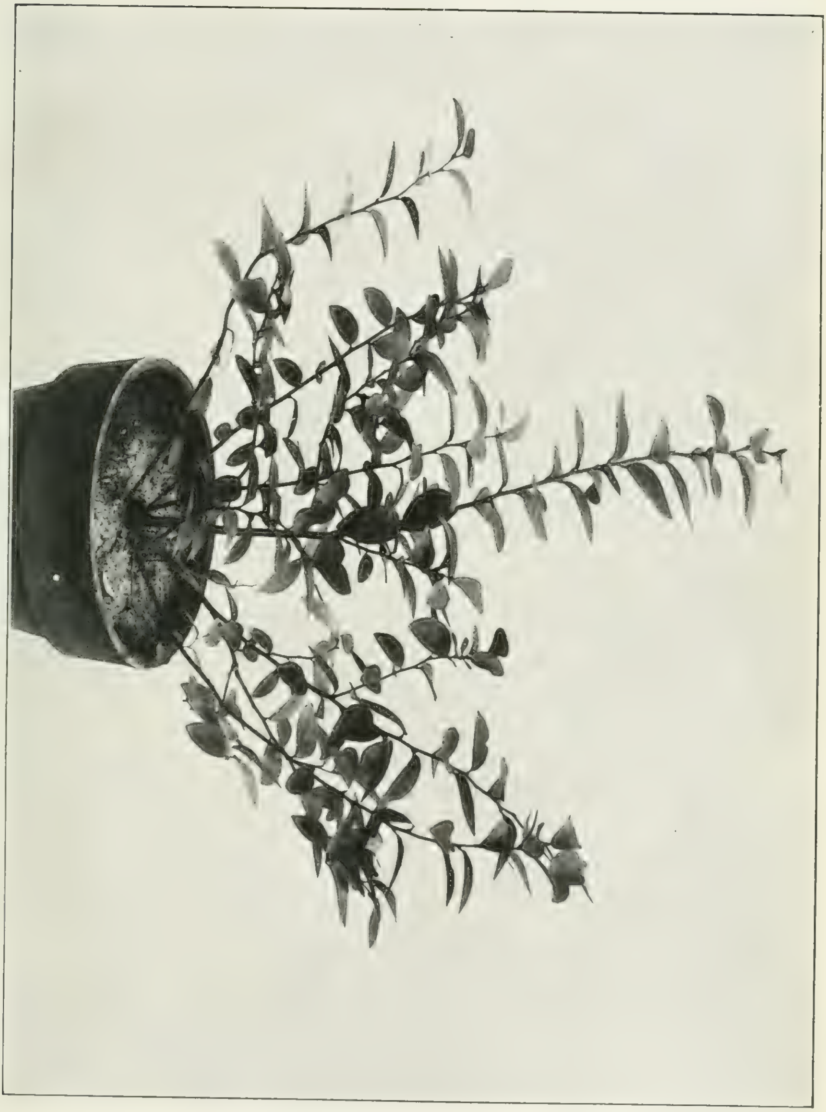
During the fall, winter, and early spring of 1908–9 a series of blueberry seedlings of 1907 was kept outdoors on a south window sill to ascertain whether repeated freezing and thawing would kill them. Most of the plants were in thin glass 3-inch pots, covered at the sides with one thickness of gray blotting paper. One plant (to which reference is again made on pp. 75 and 76) was in a 5-inch earthen pot. None of the plants were mulched or covered in any way. They were watered whenever necessary to keep the soil from drying. In cold weather the air circulated freely about the pots and the soil was repeatedly frozen solid. On warm, sunny days the melting of the ice took place rapidly. Hard freezing followed by quick thawing was many times repeated, and the conditions of exposure were such that the plants undoubtedly were subjected to a severer test for hardiness than they would ever receive under cultural conditions.

The plants passed the winter without losing any of their twigs. The wood was plump and in excellent condition when spring came, as was evidenced further by the remarkable uniformity with which every dormant bud started to grow after the first few warm days.

For the roots of some of the plants in glass pots, however, the exposure was too severe. In some of the glass pots no root growth followed the starting of the twigs, and the plants finally died. In others the root growth at first was feeble and the plants lost some of their newly started twigs by withering. Most of the plants, however, including the one in the 5-inch earthen pot, made normal growth of both twigs and roots, notwithstanding the extraordinarily severe treatment to which they had been subjected. No difficulty is anticipated, therefore, in wintering blueberry plants successfully out of doors under any ordinary cultural conditions. The seedlings of 1908 covered with oak leaves in their outdoor plunging bed of sand passed the winter of 1909–10 in good condition.

That blueberry plants must be subjected to some sort of exposure, if they are to start satisfactorily in the spring, is indicated by the behavior of certain seedlings of 1907 which were carried through the winter of 1908–9 in a rose house, where the temperature at night was about 60° F. and during the day about 10 degrees higher. These plants, although subjected to most persistent coaxing, absolutely refused to grow during the the five months from November to March, although newly germinated seedlings grew luxuriantly under exactly the same conditions.

The comparison of these indoor plants with outdoor plants may best be made by an examination of the buds shown in the accompany-



YEARLING BLUEBERRY PLANT WITH FORTY-TWO FLOWERING BUDS.

(One-fourth natural size.)

ing illustrations. made from typical indoor and outdoor specimens. The photographs reproduced in Plate XII were made on March 27, 1909. The plant shown in figure 1 of this plate was a seedling of September, 1907, which had been kept in a greenhouse all its life at a temperature suited to the growing of roses. The plant shown in Plate XII, figure 2, was identical in history with the other until October 20, 1908, when it was placed outdoors and exposed to the severest winter conditions. It was one of the window-sill plants described on page 74. The leaves shown on the indoor plant (Pl. XII, fig. 1) are those formed in the summer of 1908, which by reason of the warm temperature of the greenhouse in which the plant was wintered had never fallen off, although the plant had made no growth later than October, 1908. Neither a flowering bud nor a leaf bud has started on this plant. On the outdoor plant (Pl. XII, fig. 2) the 4 flowering buds and 62 leaf buds which had lain dormant during the winter had begun to push a few days before the picture was taken.

Plate XIII, from photographs taken on April 24, 1909, shows the same two plants nearly a month later. The leaf buds on the outdoor plant (Pl. XIII, fig. 2) have grown into leafy twigs and the flowering buds are fully opened. Of the dormant buds on the indoor plant (Pl. XIII, fig. 1) only two have started to grow. Of these two new twigs, one on the stem to the left, in the axil of the third leaf from the top, has withered its tip and stopped developing before making a full-sized leaf. The other new twig, on the stem to the right, developed abnormally from the axil of a basal bract of a flowering bud. It later made good growth and became a very vigorous shoot. All the flowering buds on this plant dried up and produced no flowers.

The erratic starting of dormant plants which have not been subjected to the conditions necessary to bring them out of their dormancy in a normal manner is well shown also in Plate XIV. This illustration is from a photograph taken February 18, 1909. The plant was a seedling of September, 1907, which was brought into the greenhouse in early December, 1908, and remained there during the winter. The illustration shows that only one of the two flowering buds on the upper twig has started, one of the four on the lower twig, and none of the leaf buds.

There can be no question that for ordinary purposes blueberry plants should be wintered outdoors. If it is desired in experimental work to force blueberry plants to fruit in a greenhouse during their second winter, it will be necessary either to etherize them or to find out some other method of treatment by which the starch in their twigs can be transformed into other carbohydrates available for the building up of new plant tissues. The writer believes that in the hard-wooded deciduous-leaved trees and shrubs of cold countries this transformation of starch will be found to be caused normally by the changes, probably enzymatic, that follow exposure to an alternation of high and low temperatures rather than exposure to a single low temperature.

(33) Dormant plants make their early spring twig growth before new roots begin to develop

The root growth of blueberry plants in early spring is very sluggish, in strong contrast to the activity of their stems. In the plant illustrated in Plate XIII, figure 2, no new root growth had taken place up to the time the photograph was made. For their early spring growth blueberry plants seem to depend on the food stored in their twigs the year before. A microscopical examination has shown that the pith and medullary rays of winter twigs are gorged with starch.

It may be of interest to state here, as bearing on the difficulty of making stem growth exhibited by an improperly wintered blueberry, that the indoor plant shown in figure 1 of Plates XII and XIII had made considerable new root growth at the stage shown in Plate XII and abundant root growth in Plate XIII. The starting of dormant buds appears from this and many other similar cases not to be influenced by the presence or absence of new root growth.

A practical suggestion based on the late spring root development of the blueberry is that transplanting may perhaps be done up to the time of flowering with little injury to the plant.

(34) Unless pollinated by an outside agency, such as insects, the flowers produce little or no fruit.

Many blueberry plants, from seed germinated in September, 1907, were brought into flower in one of the Department greenhouses during the winter of 1908-9. When left to themselves the flowers rarely produced fruit. The greenhouse contained few pollen-carrying insects, a few ants and flies merely, no bees. It was found that the flowers were so constructed as to be unable ordinarily to pollinate themselves. The lack of fruit was evidently due to lack of pollination. When pollinated artificially the flowers usually produced fruit.

In its natural position the flower (fig. 27) is not erect but inverted, the narrow orifice of the corolla being lowermost, the nectar welling up from the surface of the disk between the base of the style and the base of the filaments. The ten stamens and the style hang downward within the corolla, the stamens being shorter than the style. The pollen when mature drops down from the two anther sacs through the two anther tubes which the stamens of these plants possess and out at the terminal pores. (See fig. 28.)

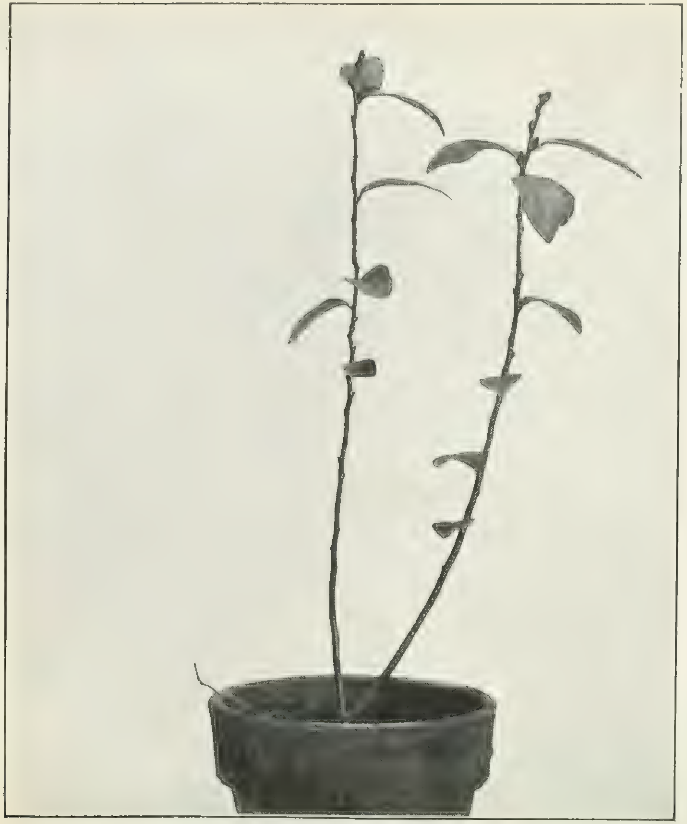


FIG. 1.—BLUEBERRY PLANT WHICH WAS WINTERED INDOORS BEGINNING GROWTH IN THE SPRING.

(Photographed March 27; one-fourth natural size.)

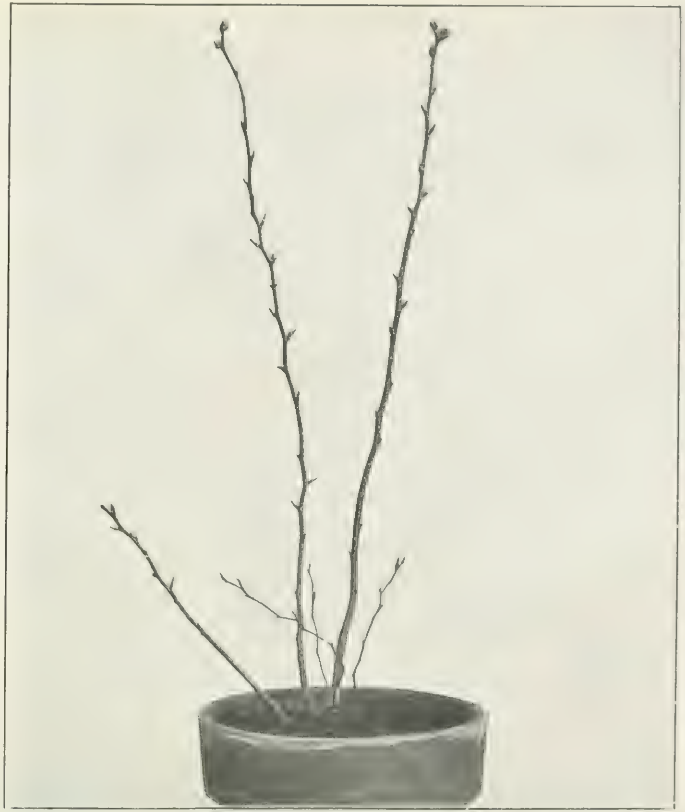


FIG. 2.—BLUEBERRY PLANT WHICH WAS WINTERED OUTDOORS BEGINNING GROWTH IN THE SPRING.

(Photographed March 27; one-fourth natural size.)

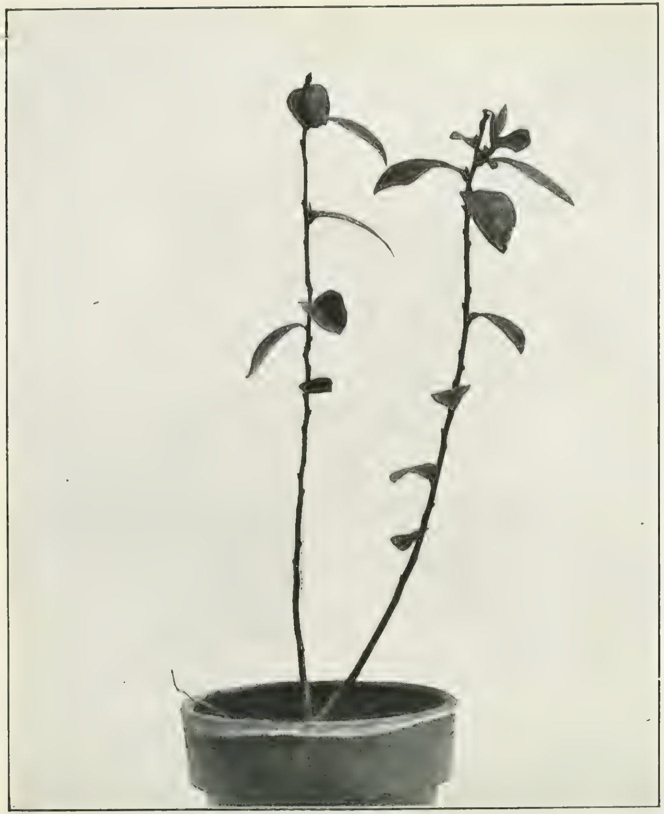


FIG. 1.—BLUEBERRY PLANT WHICH WAS WINTERED INDOORS CONTINUING GROWTH IN THE SPRING.

(Photographed April 20; one-fourth natural size.)

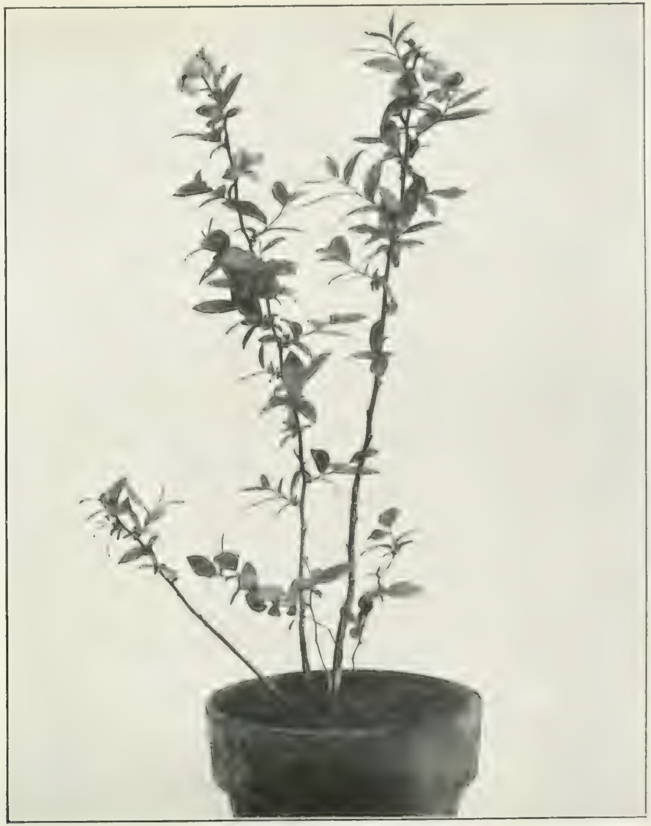


FIG. 2.—BLUEBERRY PLANT WHICH WAS WINTERED OUTDOORS CONTINUING GROWTH IN THE SPRING.

(Photographed April 20; one-fourth natural size.)

The operation of the mechanism for releasing the pollen may be observed with a high-power hand lens. The stamens hang in a close circle about the style. The filaments are broad and laced into a tight tube by the interweaving of their marginal hairs, the anther sacs press close together, and therefore the only convenient way of access to the nectar is through the slits between the anther tubes. The anther tubes are stiff and when one of them is pushed to one side the movement is communicated to the anther sac. The pollen if mature is dislodged and falls down the tube and out at the orifice.

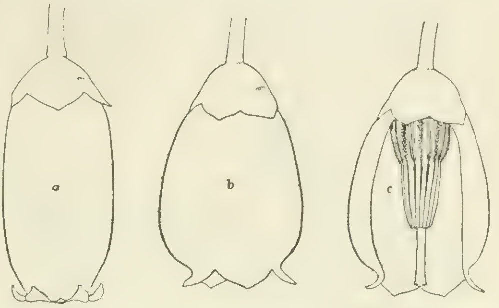


FIG. 27.—Flowers of the blueberry, from 1908 seedlings of the large-berried New Hampshire bush of *Vaccinium corymbosum: a,* Flower of the *corymbosum* type of plant; *b,* flower of the *amoenum* type of plant; *c,* same as *b,* but part of the corolla removed to show the stamens, style, and stigma. (Enlarged 3 diameters.)

The pollen does not come out of the anthers readily on a cloudy, humid day, but on a warm, sunny, dry day it accumulates in the tubes and when they are moved it runs out like grain from a grain chute. The pollen grains (fig. 29) do not stick to the sides of the parchment-like anther tubes when these are dry, but they have the faculty of adhering to hard surfaces, such as glass or the lead of a lead pencil, and they doubtless would adhere also to the hard shell of an insect whether it was covered with hairs or not.

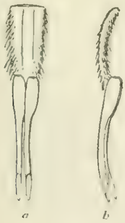


FIG. 28.—Stamens of the blueberry, from the flower shown in fig. 27, *c*: *a,* View from the inner face; *b,* side view. Both views show the broad filament with hairy margins and the anther sacs, tubes, and pores. (Enlarged 5 diameters.)

The pores of the anther tubes do not open squarely across the ends of the tubes, but they are set on a long bevel facing inward. The pollen when released would therefore fall upon the stigma were it not for a peculiarity in the structure of that organ. The sticky stigmatic surface, which the pollen must reach to effect pollination, is at the apex of the globular or top-shaped stigma, while the sides of the stigma as far up as the middle have a dry surface ending in a short collar a little wider, during the early maturity of the stigma, than the widest part of the stigmatic surface. (See fig. 30.) In the inverted position of the flower the falling pollen strikes this dry surface, like the outside of an inverted funnel, and drops off the rim or remains on it, without reaching the stigmatic surface which lies protected beneath.

Ordinarily pollination is effected by some insect which, pushing into the orifice of the corolla from beneath in search of nectar, releases the pollen, as already described. In continuing its quest for nectar the insect brushes against the stigma with some portion of its body, which is covered with pollen, either from the same flower or from some other flower previously visited.

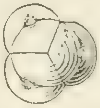


FIG. 29.—Compound pollen grain of the blueberry, consisting of four simple grains permanently cohering. (Enlarged 200 diameters.)

In pollinating the flowers by hand it was found impracticable to collect sufficient pollen to apply with a brush. The following simple and convenient method of pollination was devised: A wide opening was torn in a corolla with a pair of forceps, so that the stamens and stigma could be approached from the side. Then the lead of a lead pencil, flattened on one side and held horizontally, was brought up against the open ends of the anther tubes from below. A portion of the falling pollen was caught on the flat lead, where it could be seen easily because of the blackness of the background. Pollination was then completed by touching the stigmatic surface gently two or three times with the pollen-laden lead. A pollinated flower may be marked readily by pinching off with forceps one or more of the calyx lobes. Fruit was produced from flowers pollinated either with their own pollen or with pollen from another flower.

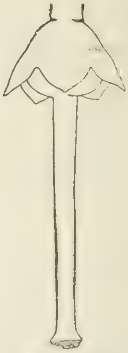
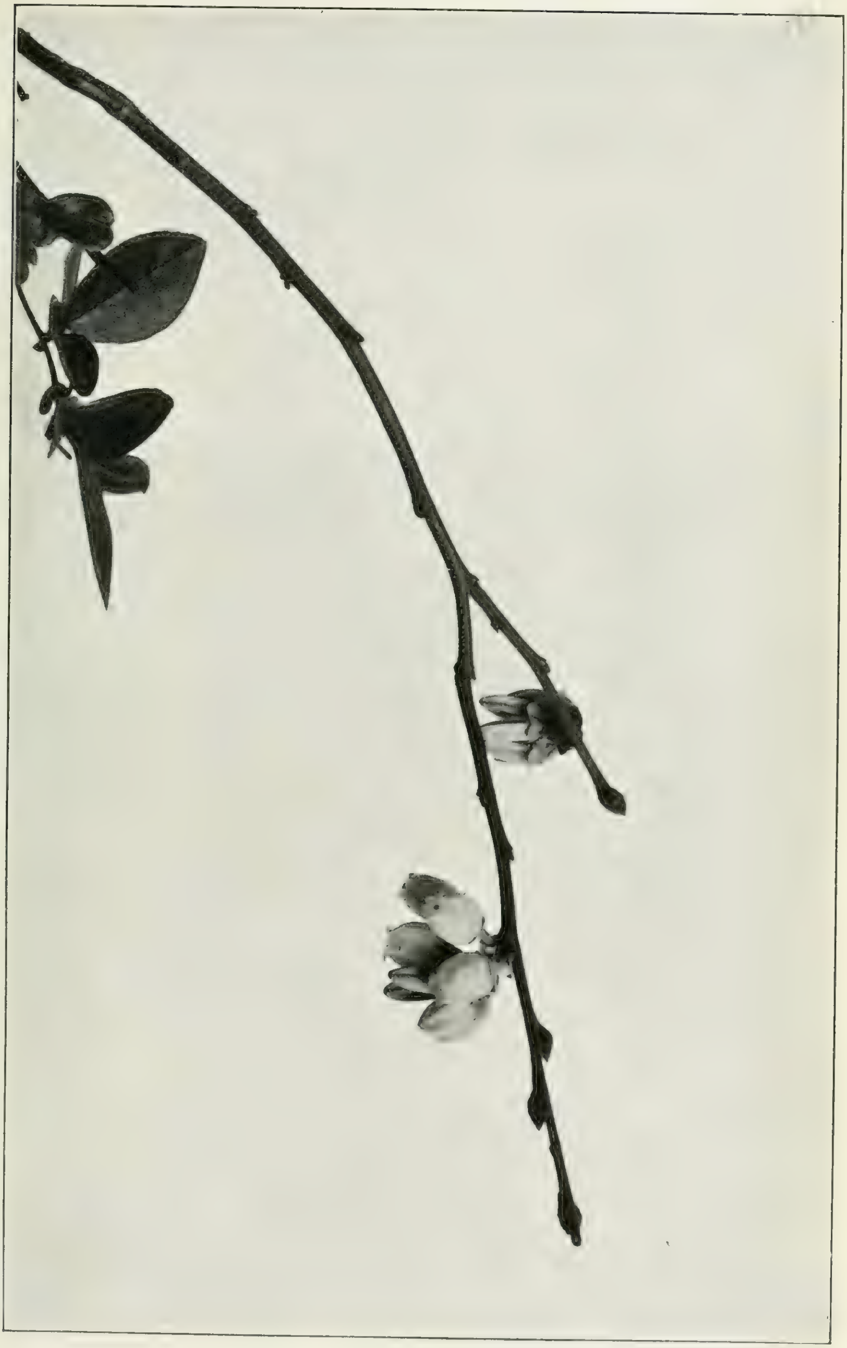


FIG. 30.—Pistil and calyx of the blueberry, showing the style and stigma. (Enlarged 5 diameters.)

The self-pollination of a blueberry flower, without insect aid, appears to occur, but only occasionally. On greenhouse plants fruit is rarely produced when the flowers are not artificially pollinated, and the same is true of outdoor plants protected from insects by a covering of gauze. The conditions of these observations were not such as to obviate all possibility of the accidental visit of some insect, but it is believed that real self-pollination occurred in some cases.

(35) THE FRUIT MATURES ABOUT TWO MONTHS AFTER THE FLOWERING.

A few days after pollination the corolla, with the stamens, falls off. The stigma at this time has turned brown, and within a day or



IRREGULAR FLOWERING OF A BLUEBERRY PLANT WINTERED INDOORS.

Only two of the six flowering buds have pushed, and none of the leaf buds. (Natural size. See p. 75.)

two the style also falls. The calyx remains permanently attached to the ovary and berry. About a week after the opening of the corolla, the ovary, which at first was much narrower than the expanded calyx, begins to swell and grow. This growth continues for about a month, and then for about another month the green berry makes little increase in size. A few days before the time of ripening the calyx turns purplish, next the green color of the berry takes on a translucent appearance, the next day it turns to a light purple, and the following day to a dark purple or whatever its permanent color may be. During these few days the berry makes a very rapid growth, its diameter often increasing 50 per cent. After reaching its permanent color the berry changes little in size, but for several days continues to improve in sweetness and flavor.

It is a characteristic of blueberries, important from the standpoint of picking, that after ripening they will remain on the bush a long time, often a month or more, without losing their plumpness or their flavor. This makes possible the removal of all the berries from a bush at one clean picking, unless to catch a fancy market a partial early picking is desired.

It is of interest to record that although the largest berry observed on the parent bush of the seedlings of September, 1907, was 0.46 of an inch in diameter, a berry ripened in the greenhouse on one of these seedlings measured on April 24, 1909 (Pl. XV), 0.49 of an inch in diameter, and August 2, 1909, one of the same seedlings had a ripe berry 0.5 of an inch in diameter.

(36) SO FAR AS OBSERVED THE SWAMP BLUEBERRY WHEN GROWN IN ACID SOILS IS LITTLE SUBJECT TO FUNGOUS DISEASES OR INSECT PESTS.

Like all plants grown in greenhouses, blueberry seedlings need to be watched in order to detect and stop promptly any fungous or insect pests that may appear.

With the exception of the Asterocystis-like root fungus described on page 65 as occurring on sickly plants in alkaline soils, the only parasitic fungus found on any of the plants was a mildew identified by Mrs. Flora W. Patterson as *Microsphaera alni vaccinii*, which appeared sparingly when the atmosphere of the greenhouse was too moist. This mildew is abundant on *Vaccinium vacillans*, both wild and cultivated, but the swamp blueberry is very little subject to its attacks, an important characteristic. This fungus would doubtless respond readily to the ordinary treatment for mildew with pulverized sulphur.

Among insects a green aphis sometimes threatened to damage the growing twigs, but it was easily destroyed by tobacco fumigation.

The greenhouse red spider (*Tetranychus bimaculatus*) infested some of the cultures, especially in the warmer greenhouses, occurring chiefly on the backs of the leaves, and seriously injured the plants unless promptly checked. The most satisfactory treatment was to syringe the plants once or more a day with a swift spray of water, repeating the treatment until the animals were cleared off.

A pathological condition observed in the summers of both 1908 and 1909, at first supposed to be physiological in cause, has now been traced to an insect. The young leaves of tender shoots become semi-transparent or "watery" in appearance, remain small, develop a faintly rusty color on the lower surface, tend to become slightly cockled, and sometimes turn brown and wither. It was finally observed that these leaves were infested with a very minute animal, much smaller than a red spider and when not in motion difficult to distinguish with a strong hand lens. Specimens submitted to Mr. Nathan Banks, of the Bureau of Entomology, were identified by him as a mite of the genus Tarsonemus and belonging probably to an undescribed species.

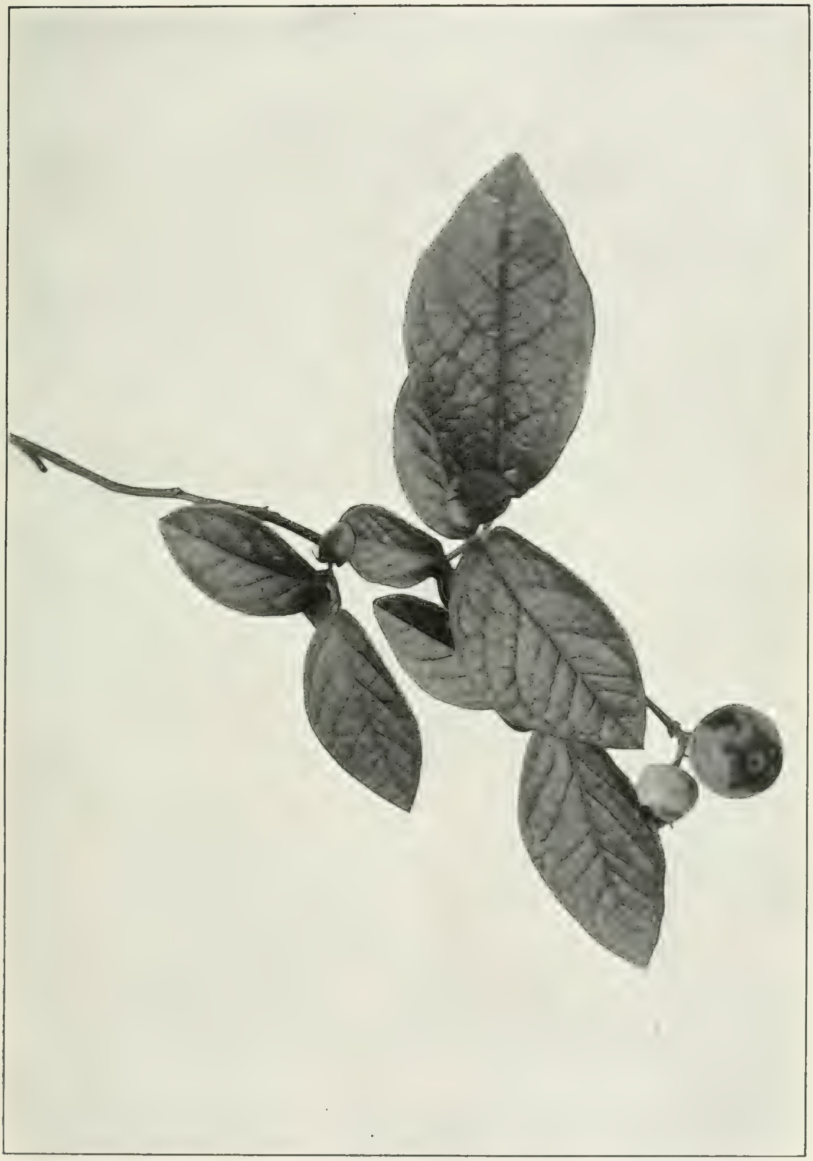
A similar and perhaps identical mite had done considerable damage to young seedlings in the greenhouse during the winter of 1908–9, its presence being indicated by the conspicuous cockling of the leaves. The difficulty had then been met by the pruning of the affected twigs. It was observed, however, in the summer of 1909 that the mite producing the watery appearance of the leaves did not occur on outdoor plants fully exposed to rain and dew, but only on plants partly or wholly protected by glass. It is suggested, therefore, that frequent syringing with water may be the proper means to control this mite.

On the whole, this species of blueberry when properly grown may be regarded as unusually free from the depredations of fungi and insects.

IMPROVEMENT AND PROPAGATION.

(37) THE PARENT PLANT OF THE SWAMP BLUEBERRY SEEDLINGS, THE CULTURE OF WHICH HAS BEEN DESCRIBED, BORE BERRIES OVER HALF AN INCH IN DIAMETER.

The parent of the blueberry seedlings of 1908 was a bush of *Vaccinium corymbosum* selected at Greenfield, N. H., in July, 1908, after three summers of cursory observation in the mountains of southern New Hampshire and three weeks of diligent search in the summer of 1908. The bush grew at an elevation of 950 feet above the sea. It stood with many other blueberry bushes in an old, brushy, mountain pasture, in permanently moist but not swampy soil. It was about 7 feet in height, and the largest of the several stems was about 2 inches in diameter. The plant was old and somewhat decrepit, the tops on some of the stems being partially dead. Some parts of the bush, however, were in full vigor, with robust foliage and twigs. The leaves were dark green above and pale glaucous green beneath, with entire margins, and smooth on both sides except for a slight pubescence on the midrib and principal



BERRY RIPENED ON A BLUEBERRY SEEDLING AT THE AGE OF NINETEEN MONTHS.

(Natural size.)

veins of the upper surface. They were of large size, on the fruiting twigs reaching a length of 2 inches and a breadth of 1 inch and on vigorous shoots having the corresponding measurements 2.5 and 1.5 inches. The character of the leaves is mentioned in detail because of the remarkable variation shown in the leaves of the seedlings, particularly in size, toothing, color, and pubescence. The large flowers produced in the spring of 1909 were 0.4 of an inch (10 mm.) long from the base of the ovary to the tip of the corolla; the sepals were very short, and the corolla white and nearly cylindrical.

The berries were of large size, reaching a diameter of over half an inch. The color was an unusually pale blue, due to a dense bloom or glaucousness over the nearly black surface. In form the berry was not spherical, but somewhat depressed or tomato shaped. The calyx in the ripe berry (Pl. VI, fig. 1) was almost obliterated, because it was small in the beginning and because of lateral stretching of the berry in acquiring its depressed form. This smallness of calyx is of importance, because in such a berry no shelter is afforded beneath the sepals for insects, and also because the amount of "rag," or indigestible skin, is much less than in a berry with a large calyx. In flavor the berry was exceptionally good. It was sufficiently acid to be decidedly superior to the mild, sweet berry of *Vaccinium pennsylvanicum*, yet not sour like the berry of *V. canadense*. It represents one of the best types of flavor in the variable *V. corymbosum*.

The only unfavorable feature of this bush was the lateness in the maturity of its berries, a characteristic of the species to which it belongs. The earliest New England berries, which bring the fancy wholesale price of 20 cents or more per quart for the first few days, as described on page 12, are those of the dwarf *Vaccinium pennsylvanicum*, which mature about two weeks earlier than those of *V. corymbosum*.

The size of the berry is of such importance as to warrant an exact record of the measurement, not only of the largest berries but of all the berries from an average picking. On August 2, 1908, an average pint of berries was taken out of a clean picking of this bush and each berry was measured. The measuring was done by means of a metal plate containing a series of circular holes 5, 6, 7 mm., etc., in diameter. The pint of berries showed the following sizes:

Diameter of berry.	Number of berries.
7 to 8 mm	2
8 to 9 mm	50
9 to 10 mm	191
10 to 11 mm	278
11 to 12 mm	137
12 to 13 mm	10
13 to 14 mm	3
	671

The largest berry measured on this bush was 14.02 mm. (0.552 of an inch) in diameter.

Three quarts of berries were picked from the bush; all those less than 10 mm. in diameter were discarded, and the remainder, about 2 quarts, were carried to Washington for seed purposes.

(38) THERE IS EVERY REASON TO BELIEVE THAT THE BLUEBERRY CAN BE IMPROVED BY BREEDING AND BY SELECTION.

The swamp blueberry (*Vaccinium corymbosum*) is an exceedingly variable bush. There are three especially well-marked forms, called *V. amoenum*, *V. atrococcum*, and *V. pallidum*, by some authors regarded as distinct species, by others as forms of *V. corymbosum*. Within the limits of these forms variation is also extensive. There is great opportunity for selection among wild varieties in the size, color, flavor, and time of ripening of the berries and in the productiveness and vigor of the bushes.

That types possessing desirable qualities can be crossed there is no question. A method of pollination has already been described (see p. 78), which, supplemented by the removal of the stamens on the female parent before they have matured their pollen and also by the protection of the pollinated flowers from insects, would insure a genuine cross.

The possibility of securing valuable varieties is accentuated by the marked variation observed in the character of the offspring of the large-berried bush from which the seedlings of 1908 were grown. Besides minor variations, these seedlings show three forms which may be regarded as types. One of these, characterized by its low stature and leaves tending to be conduplicate and by its long persistence into the winter in a green state, is perhaps the result of some pathological difficulty. Two of the types, however, appear in every way to be normal. One has its leaves large, obovate-elliptical, glaucous on the back, and with entire margins, such as are possessed by the parent and are typical of true *Vaccinium corymbosum*, and it develops only a few though very robust stems, with few flowering buds. The other has smaller, narrower leaves, green on both surfaces, and with margins closely and evenly serrulate. It produces many stems smaller than those of the other, and more numerous flowering buds. It is strongly suggestive of the plant called *Vaccinium amoenum*. It is much larger and more robust than *V. pennsylvanicum*, and may possibly be a hybrid between that species and *V. corymbosum*.

The characters of bush and foliage in these two types have not yet been correlated with any differences they may show in flower and fruit. It is, however, of great interest that these same two types occur among the seedlings of 1907, as well as those of 1908, which came from a different though similar bush growing about 2 miles from the other.

(39) THE SWAMP BLUEBERRY HAS BEEN PROPAGATED BY GRAFTING, BY BUDDING, BY LAYERING, BY TWIG CUTTINGS, AND BY ROOT CUTTINGS.

On March 2, 1909, a few scions of the large-berried bush from New Hampshire, dormant winter twigs, were grafted on seedlings of 1907 which had been started into growth in the greenhouse. The actual work of grafting was done by Mr. Edward Goucher. All were simple splice grafts, the diagonal cut being about 0.75 of an inch in length, the diameter of stock and scion at the point of contact about 0.15 of an inch, and the length of the scion about 2.5 inches after it was cut off at the tip just below the lowest flowering bud. The splice was wrapped tightly and completely with raffia, but no wax was applied except to the cut tip of the scion. In order to prevent a possible injurious degree of evaporation from the scion, the whole graft, which was near the base of the plant, was surrounded nearly to the tip of the scion with a loose mass of sphagnum, which was kept slightly moist though well aerated.

All the scions put out new growth from their buds in about ten days. In half the grafts union did not take place, the new growth finally collapsed, and the scion died. In the others the surfaces united satisfactorily and the wrapping was removed. By the end of the season of 1909 the grafts had made a growth of 5 to 8 inches and had laid down flowering buds. (See Pl. XVI, fig. 1.)

The first experiments in budding were begun on August 13, 1909, the work being done by Mr. Henry H. Boyle. Seven seedlings of 1906 and 1907 were budded with summer leaf buds of the large-berried *Vaccinium corymbosum* bush from New Hampshire. On August 16, 6 other seedlings of 1906 and 1907 were budded with buds from large-berried plants of *V. pallidum* from North Carolina. On September 2 and 3, 1909, 26 more seedlings, of 1907 and 1908, were budded with buds from the New Hampshire bush. The buds were inserted near the base of the plant on stems 0.25 to 0.5 of an inch in diameter. The method of procedure was that used in ordinary budding, as of peaches, the same T-shaped cut being made in the bark of the stock, the bud wood cut to the length of half an inch or a little more, and the bud after insertion wrapped tightly with raffia.

The percentage of success in the budding was small. Out of the 39 plants budded only 16 retained their bud alive and in apparently good condition at the end of the season, and the following spring only 5 were alive and in condition to grow. Plate XVI, figure 2, is a reproduction of a photograph of one of the successful buds from the large-berried New Hampshire bush, taken in the winter of 1909–10 after union had taken place, the wrapping had been removed, and the stock had been cut off above the bud.

Comments on some of the features of these budding experiments may be useful to other experimenters. The growth of the stems during the portion of the season remaining after the budding was sufficient to strain the wrappings and, unless the bud wood was held tightly for its whole length, to push the bud out of place. It was found best to leave the bud tightly wrapped to the end of the season, notwithstanding the fact that the stock might become deeply creased and choked.

An examination of the buds that failed showed that in most cases bark or callus from the stock had intruded between the stock wood and the bud wood, sometimes covering the entire surface. While the bud wood in some such cases was in part still alive and green, it was of course doomed.

As late as August 30 in New Hampshire, and September 3 in Massachusetts, bushes of the swamp blueberry were found in which the bark would peel and buds could be inserted. On September 2 no wild bushes of *Vaccinium atrococcum* could be found at Washington in condition to bud. Even in Massachusetts and New Hampshire, on the dates mentioned, most of the bark on all the bushes and all of it on many bushes would not peel. Bark still in good condition occurred mostly on vigorous shoots of the season and in some cases of the preceding season. Sometimes the bark on the north side of an erect shoot would peel when that on the south side would not. Bark still green and whole would peel when near-by bark which from age and exposure had begun to turn brown and split on the surface would not peel.

Propagation by layering was carried on in 1908 and 1909. In the greenhouse experiments moist live sphagnum proved to be a more successful material than peat and sand in which to root a layered branch. When the branch laid down was one which was hardening its wood but still bearing leaves, it callused and rooted readily in the sphagnum at the point where the bark was sliced, but when a young soft-wooded branch was used it usually began to decay at the cut and finally died. Although several times tried it was never found practicable to sever a layered and rooted branch from the parent plant successfully except at the period of winter dormancy after the leaves had been shed.

(40) THE MOST DESIRABLE METHOD OF PROPAGATING THE SWAMP BLUEBERRY IS BY CUTTINGS.

While the surest method of propagating a selected blueberry bush is by layering, and the most rapid method of securing fruiting plants from it is by grafting, both these methods have certain objections which do not apply to the method of propagation by cuttings.

Propagation by grafting is objectionable because of the habit the blueberry plant has of continually sending up new shoots to replace the old stems. These shoots come from the root or from the base of

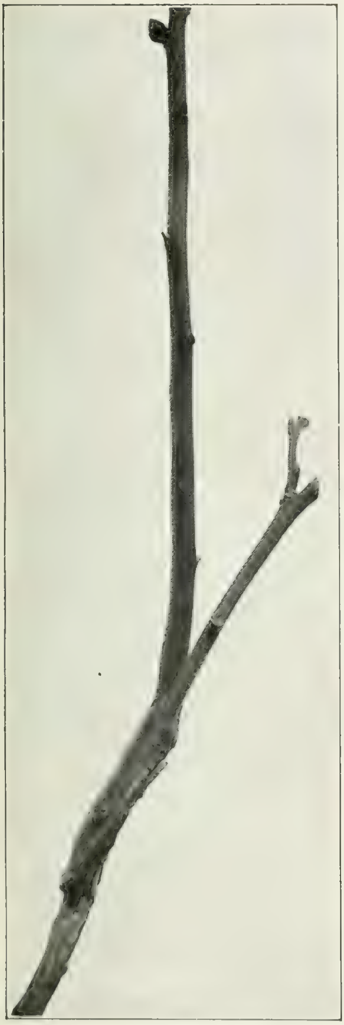


FIG. 1.—GRAFTED BLUEBERRY.

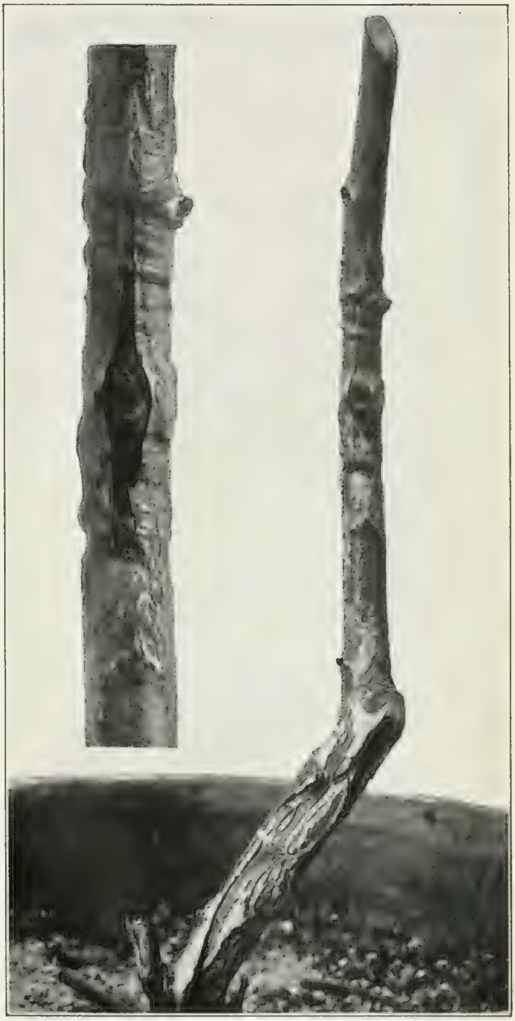


FIG. 2.—BLUEBERRY SEEDLING SUCCESSFULLY BUDDED.

The line of union between the stock and the scion in figure 1 is clearly shown. Two twigs had grown from the scion, a short one near the tip and a vigorous one from the lower part. In figure 2 is shown an inserted bud which has united successfully with the stock, but has not yet begun to grow. The inset figure is about three times natural size. The two main figures are natural size.

the stem just below the surface of the ground. Originating below the graft they would not bear fruit of the variety desired, and such a grafted plant would always be liable to serious depreciation in value. It is suggested, however, for the benefit of any who may desire to follow up this method of propagation, that a plant produced by root grafting would be somewhat less liable than a stem graft to the production of shoots from the stock.

Propagation by layering is not open to the objection just raised against propagation by grafting. The difficulty with layering is that only a few plants can be propagated from a parent in this way at one time. The method of layering is slow and therefore, from a commercial point of view, faulty.

Propagation by cuttings, whether of the root or the stem, is subject to neither of the objections raised to grafting and to layering. In a plant raised from a cutting the whole plant body, including the root, is of the variety desired, and alien shoots can never be produced. Furthermore, hundreds or even thousands of cuttings may be taken at one time from a valuable plant and a large stock of offspring can soon be accumulated.

The present objection to the propagation of the swamp blueberry by cuttings is the difficulty of making a high percentage of the cuttings grow. In this respect the experience of the last two years may be characterized as a series of frequent alternations of high hopes and disappointing failures. The intimate knowledge, however, acquired from these experiments regarding the behavior of cuttings under many different conditions gives ground for confidence in ultimate success; but as we are only in the middle of things in this matter a full description of the experiments with cuttings must be deferred until satisfactory results shall confirm our confidence in the methods used.

For the present it may suffice to show an illustration of a plant from a root cutting (fig. 31) and another of plants from twig cuttings (Pl. XVII) of the big-berried bush from Greenfield, N. H. In Plate XVIII is illustrated, from a photograph taken in the winter of 1909–10, a plant grown from a cutting taken on October 15, 1908, from a seedling of September, 1907. Although itself only a year old, and even then taken from a seedling only a year old, the plant after passing the winter of 1908–9 in the greenhouse and the summer of 1909 outdoors, had laid down 156 flowering buds at the time it was photographed.

While these cases show that swamp blueberry plants can be produced successfully from root cuttings and stem cuttings, the successes have been so erratically distributed that the recommendation of any particular method is hardly warranted at the present time.

It should be stated here that those species of blueberry which spread by rootstocks, such as *Vaccinium pennsylvanicum*, and other related plants having the same habit, like the deerberry (*Polycodium stamineum*) and the dwarf huckleberry (*Gaylussacia dumosa*), have been reproduced without difficulty by rootstock cuttings. This method is not generally applicable to the swamp blueberry, however, as large plants of this species seldom produce rootstocks.

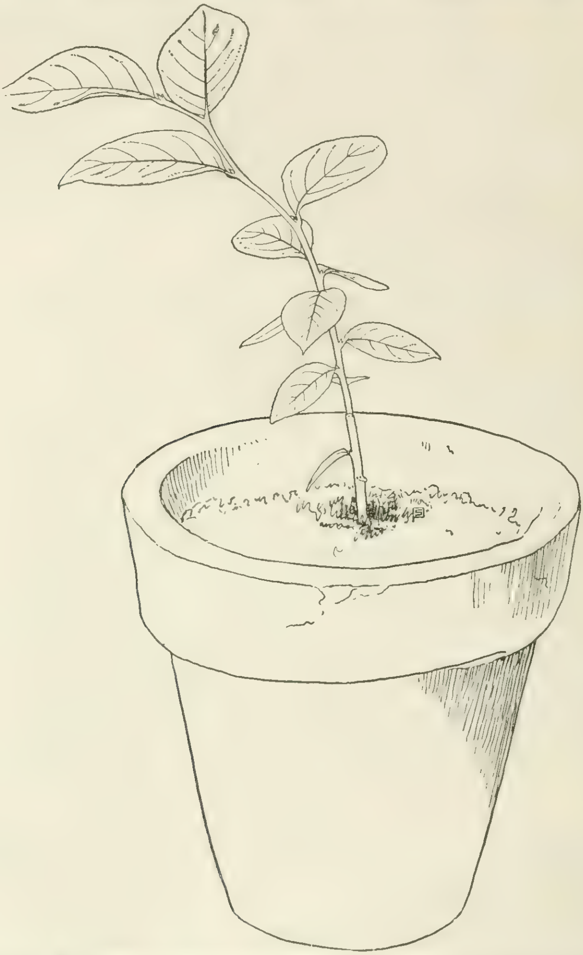
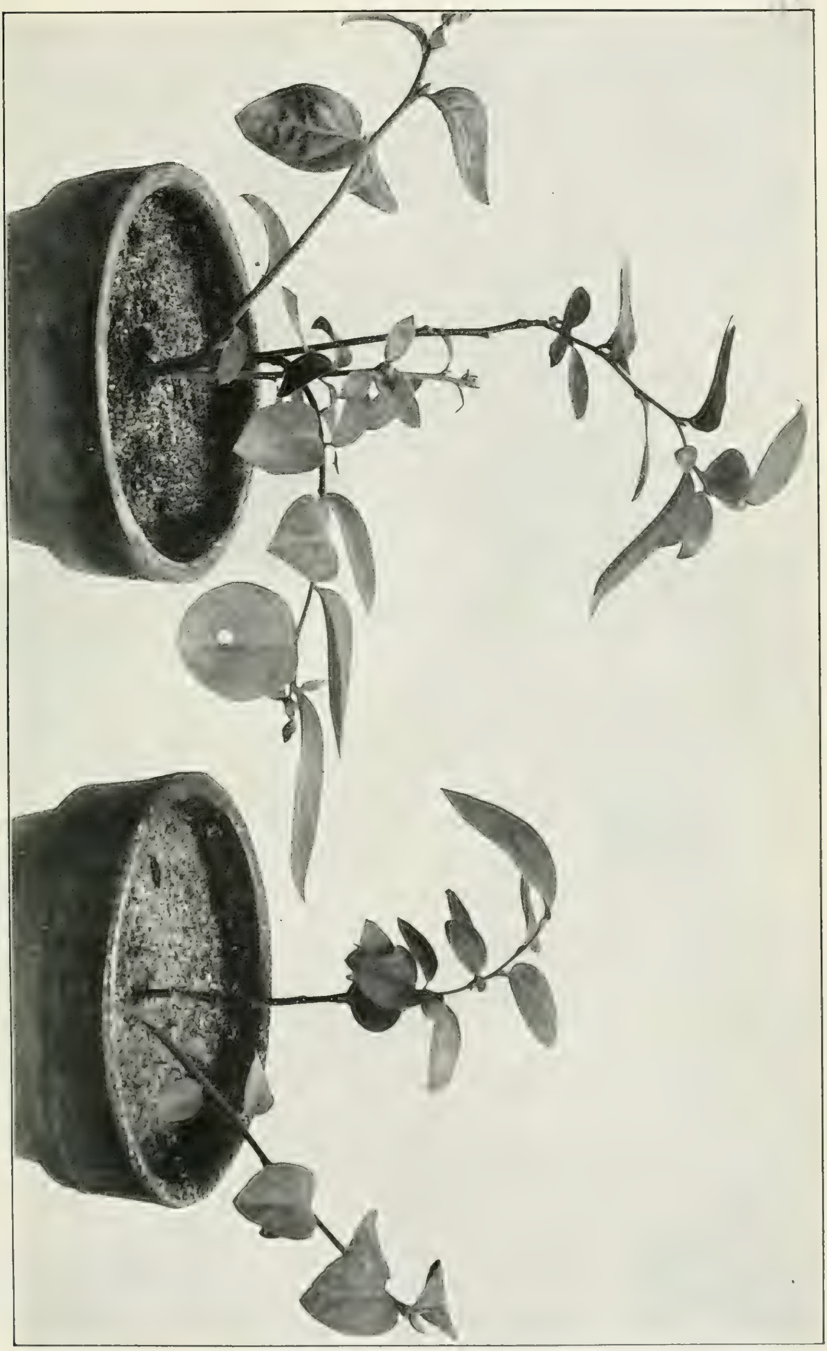


Fig. 31.—Blueberry plant grown from a root cutting. (Natural size.)

FIELD CULTURE.

(41) Experiments have been begun in the field culture of the swamp blueberry.

While the results of the pot culture experiments are regarded as highly successful and satisfactory, the experimental field plantings made in 1908 and 1909 can not be said to have given more than



BLUEBERRY PLANTS FROM TWIG CUTTINGS.

(One-half natural size.)

promising results. It is true that out of one planting of 179 seedlings of 1907 made in a partially moist natural meadow at Greenfield, N. H., in early July, 1908, 97 per cent outlived the severe drought of that summer and the rigors of the following winter, and 6 per cent flowered and set fruit. The plants were not observed during the ripening season. While this record of flowering and fruiting in plants 2 years of age may be regarded as satisfactory in comparison with the several years supposed by the earlier experimenters to be required before fruiting, it nevertheless can not be regarded as satisfactory in comparison with the pot cultures from the seedlings of 1908, of which, as stated on page 73, 70 per cent were prepared to flower in 1910, their second year.

While the results of the field experiments thus far made are regarded as in no wise approaching what may confidently and reasonably be expected, they nevertheless may serve even at this early stage to convey some useful lessons.

The field planting of 179 plants already referred to contained 84 plants which had never been potted but were torn apart out of their original seed flat while in full growth and set outdoors in the place indicated. These plants after such severe treatment never grew to be robust and none of them flowered. It was among them that all but two of the deaths in the field occurred. That any of the plants should survive such rough usage is of interest experimentally, but in actual practice such a method should never of course be followed.

Most of the field plantings were made in areas where the natural soil had been chopped with a mattock to the diameter of about 18 inches and the depth of about 8 inches immediately before the planting. It is evident from the comparison of certain plantings made in 1909 that a growing plant when set out in such freshly chopped soil receives a serious setback. On June 4, 1909, 216 seedlings of 1908 were set out in new holes prepared as described above, and 48 other seedlings of 1908 were used at the same time to replace dead or feeble plants set out in the preceding year. These 48 plants therefore went into soil that had rotted for a year, although it was in part penetrated again by new roots from the surrounding native vegetation. When next examined, on June 30, the two groups of plants showed the most marked difference in growth. The plants in the new holes showed the same purpling of the leaves and cessation of growth as did plants in the greenhouse when suffering from excessive acidity due to potting in raw peat. (See p. 60.) The plants in the old holes, on the contrary, were nearly all of good color and growing well. It is inferred from this observation that blueberry plants will do better if the holes in which they are set are filled with peat or peat mixture the acidity of which has been tempered by several months of decomposition.

In all the field plantings thus far made the plants were set out while in full growth. Although most of them were in pots when transplanted, and therefore carried their entire root system with them, nevertheless it is regarded as highly probable that a better plan would be to set the plants out when dormant, in the early spring of their second year. Such a plan would offer several advantages which it is hardly necessary to recount.

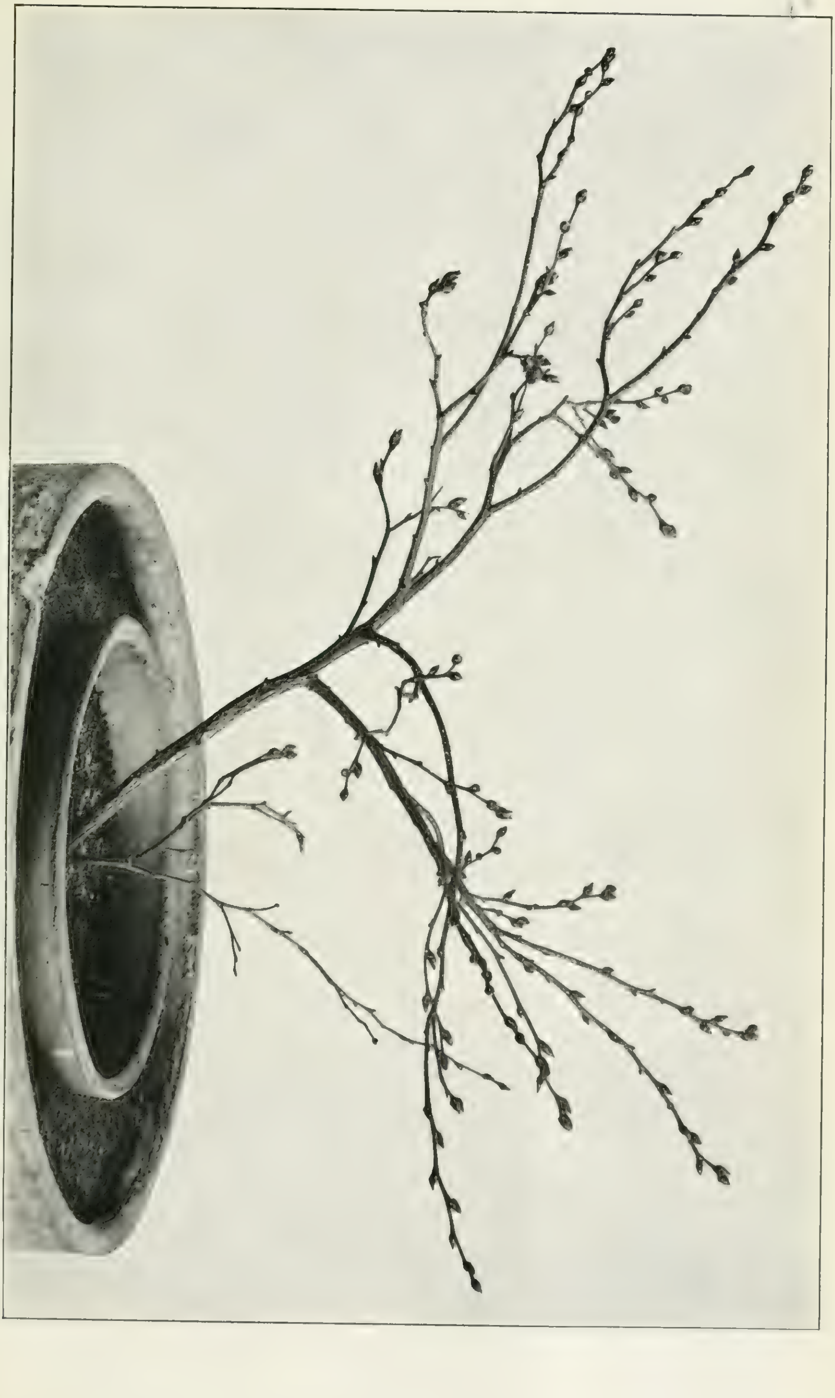
For several days after transplanting, the plants were partially shaded. Paper and the branches of various trees and bushes were tried for this purpose. Pine branches stuck in the ground on the south side of the plants were found by far the best of the shades used.

The soil about the plants was mulched in most cases with dead leaves, held in place when necessary by a little earth thrown over them.

CONCLUSION.

In conclusion, to those desiring to experiment with the field culture of the swamp blueberry, whether with wild plants, seedlings, or plants grown from cuttings, two modes of treatment are suggested, both deduced from the experiments already made. The first method, suited to upland soils, is to set the plants in trenches or separate holes in well-rotted peat at least a foot in depth, and mulch the surface well either with leaves or with clean sand. The excavations should provide ample space for new growth of the roots, not less than a foot each way from the surface of the old root ball. The peat used may be of either the bog or upland type, as described on pages 32 to 35 of this publication, and should have been rotted for several months before using. The soil in which the holes or trenches are situated should be such as to provide good drainage, the ideal condition of the peat about the roots of the plant being one of continued moisture during the growing season, but with all the free water draining away readily so that thorough aeration of the mass of peat is assured. If the surrounding soil is sufficiently porous to insure the maintenance of such a moist and aerated condition, without the necessity of mixing sand with the peat, better growth, it is believed, will be secured than when such a mixture is used.

The second method of field culture suggested is to set out the plants in a peat bog after the bog has been drained, turfed, and deeply mulched with sand. The treatment proposed is the same as that employed in cranberry culture, except that no special provision need be made for rapid flooding of the bog for winter. The ground water in the bog may probably be kept with advantage a little lower than is usual with cranberries. This method of culture is suggested not



BLUEBERRY PLANT FROM A TWIG CUTTING.

Photographed in the winter after the plant was 1 year old. The pot is plunged in sand, in a larger pot. (One-half natural size. See p. 85.)

only because of the close botanical relationship of the swamp blueberry and the cranberry and the known similarity of their physiological requirements in the matter of peat and moisture, as well as the presence of a mycorrhizal fungus in the roots of both, but also and especially because the most robust growth in all the pot experiments occurred when the roots of the plant were feeding on pure peat and the pots were surrounded by moist sand. The important effects of these conditions are discussed on pages 68 to 71. Essentially the same effects, it is believed, are secured by the system of culture used for the cranberry.

This publication closes with no special summary of results. The numbered statements which form its framework are in themselves a sufficient summary for the general reader, and one who is led by these experiments to undertake the culture of the blueberry will find it profitable not to begin his work until he has read the whole of the publication. These plants differ in their soil requirements so fundamentally from all our common cultivated crops that it is useless to expect to succeed with their culture without a thorough understanding of the principles governing their growth.

Those desiring to look into the work of earlier experimenters can find a key to the literature in F. W. Card's book entitled "Bush Fruits," or in the article by W. M. Munson on Vaccinium, in Bailey's Cyclopedia of American Horticulture.

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A WELL-KEPT YELLOW TRANSPARENT APPLE ORCHARD IN DELAWARE, ABOUT 10 YEARS OLD.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 194.
B. T. GALLOWAY, *Chief of Bureau.*

SUMMER APPLES IN THE MIDDLE ATLANTIC STATES.

BY

H. P. GOULD,
POMOLOGIST IN CHARGE OF FRUIT DISTRICT
INVESTIGATIONS.

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SCIENTIFIC STAFF.

A. V. Stubenrauch, *Expert Acting in Charge.*

A. V. Stubenrauch, *Expert in Charge of Fruit Transportation and Storage Investigations.*
G. C. Husmann and H. P. Gould, *Pomologists.*
A. D. Shamel, *Physiologist.*
S. J. Dennis, H. J. Ramsey, C. S. Pomeroy, A. W. McKay, Richard Schmidt, Gilbert H. Crawford, Jr., and C. G. Patten, *Experts.*
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C. A. Reed, *Special Agent.*
F. L. Husmann, *Viticultural Superintendent.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 25, 1910.

Sir: I have the honor to transmit herewith a manuscript entitled "Summer Apples in the Middle Atlantic States" and to recommend that it be published as Bulletin No. 194 of the series of this Bureau. This bulletin was prepared by Mr. H. P. Gould, Pomologist in Charge of Fruit District Investigations, and is coordinate in character with Bulletin No. 135 of the Bureau series, entitled "Orchard Fruits in the Piedmont and Blue Ridge Regions of Virginia and the South Atlantic States." It has been submitted by Mr. A. V. Stubenrauch, Expert Acting in Charge of Field Investigations in Pomology, with a view to its publication.

The information contained in this bulletin results from a systematic investigation which is now in progress by this Bureau in different fruit-growing regions of the country. The object of this work is to determine as far as possible the adaptability of fruit varieties to different conditions and the particular climatic and other requirements of different varieties.

The growing importance of early-apple culture and the increasing demand for fruit of this character have warranted the giving of special attention to this phase of fruit growing. In certain sections of the region referred to in this bulletin early-apple culture is of great importance not only because of its present degree of profitableness, but because of the fact that it has developed largely in the place of a declining peach industry.

While the varietal data and other information are based on the conditions which exist in this region and hence are not directly applicable elsewhere, it is expected that fruit growers in other regions who may be interested in the growing of summer apples will find the discussions of value to them.

The writer wishes to acknowledge his indebtedness to the many fruit growers in this region who have without reserve given him the freedom of their orchards and the benefits of their experience in the course of the field work connected with these investigations. The assistance of his office associates in the identification of varieties and in other ways has also aided the writer very materially in the preparation of this bulletin.

Respectfully,

Wm. A. Taylor,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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SUMMER APPLES IN THE MIDDLE ATLANTIC STATES.

INTRODUCTION.

The extensive and systematic growing of early-ripening or "summer" varieties of apples for commercial purposes is one of the comparatively recent developments of the fruit industry. Such varieties have always had a place in the family orchard, and in seasons of abundant crops the fruit from these trees has often been sold in the local markets. Occasional commercial orchards, since the early days of the fruit industry, have contained a few trees of early varieties, the fruit of which has been shipped by express or otherwise to more or less distant markets, but in most commercial apple-growing sections early varieties have not been considered worth including in extensive fruit-growing projects. In some sections, however, during the past ten or twenty years, and especially during the last decade, the attention of fruit growers has been directed more and more to the possibilities in this direction.

A considerable demand has developed for summer apples. This demand is growing; new markets are being reached. During the past few seasons fruit growers and shippers have received an increasing number of requests from commission houses and fruit dealers for fruit of this class. Though this demand may in a measure be variously influenced from year to year by the abundance of peaches and other fruit in the market during the early-apple season, it shows an increasing appreciation of the important place which summer apples may be made to fill.

In the Middle Atlantic States, and especially in the Coastal Plain or "tidewater" region, there are several sections in which the growing of summer apples has already become an important feature of fruit growing. This phase of the fruit industry has been greatly extended here in recent years and is being still further developed. It is believed that other sections of these States, where little or no fruit is now grown, are also capable of being developed along this line. This bulletin describes the region mentioned - its conditions, advantages, and possibilities in relation to the production of early apples - and contains a discussion of the principal varieties now grown there, with a view to indicating their relative value in the further development of the early-apple industry in this region.

DESCRIPTION OF THE COASTAL PLAIN REGION.

On account of the relative importance of the early-apple industry in the Coastal Plain region, in comparison with other sections in the Middle Atlantic States, it is a matter of convenience to adopt this region as a geographical unit of territory in this bulletin and to base comparisons and discussions on the observations made there. Its location and extent are indicated below.

GEOGRAPHICAL LOCATION.

In a general way, the division line in the Middle Atlantic States between the region commonly termed the Coastal Plain and the adjacent territory is indicated on the map shown as figure 1 by a conspicuous unbroken line. This line may be said to start in New Jersey at the mouth of the Raritan River where it empties into the bay of that name, extending in a southwesterly direction to Trenton. The Delaware River forms the division between New Jersey and Pennsylvania south of Trenton. The dividing line then continues in a southwesterly direction across northern Delaware and the eastern shore of Maryland, passing in the vicinity of Chestertown. Crossing the Chesapeake Bay, it reaches Anne Arundel County a few miles north of Annapolis and continues in the same direction to the District of Columbia. In Virginia the direction of this boundary is slightly southwest from Alexandria to the vicinity of Fredericksburg and includes a narrow strip of land along the Potomac River between these two cities. From the latter a southerly direction is followed, passing near Richmond and Emporia. A southwesterly direction is followed in crossing North Carolina, passing near Raleigh and reaching the South Carolina line at a point nearly south of Rockingham, the county seat of Richmond County, N. C. In the same arbitrary way the state line between North and South Carolina is taken as the southern limit of the region under discussion.

From a purely geographical standpoint the corresponding area of South Carolina and Georgia should be included in this unit of territory, but as practically no apples are grown in these sections they are not specifically included in the present discussion. And further, it is generally conceded that these sections are not well adapted to apple culture on account of the climatic conditions which result from their low elevation and low latitude.

It is believed, however, that the development of the early-apple industry is practicable in that part of the area of the Middle Atlantic States which lies between the Coastal Plain and the 500-foot contour (this being largely an arbitrary boundary line). The approximate position of this contour is indicated on the map (fig. 1) by a broken line. The conditions of this section are such that the discussions which follow, though based on the Coastal Plain, would doubtless be applicable, with only minor modifications, to this area.

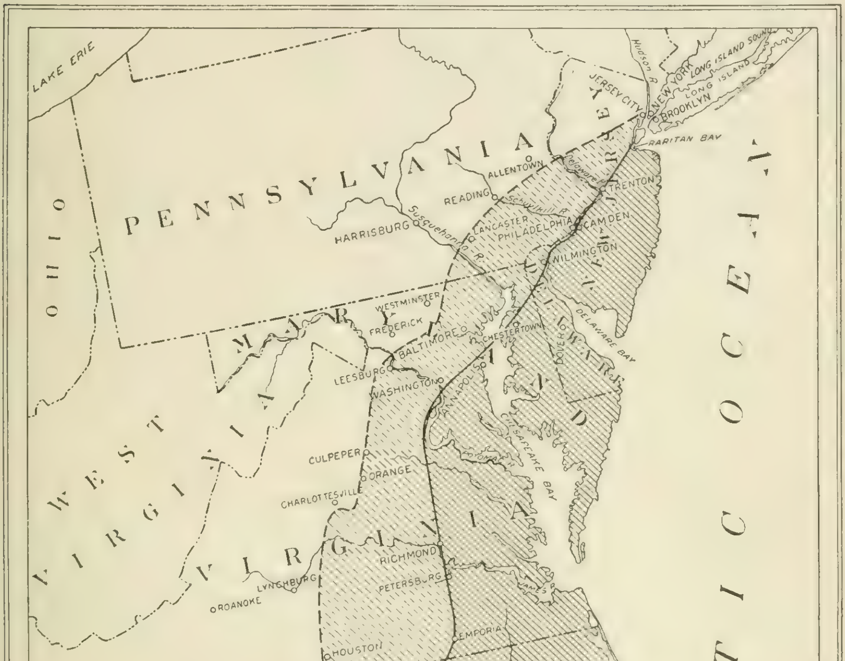
LAKE ERIE
OHIO
PENNSYLVANIA
NEW JERSEY
NEW YORK
JERSEY CITY
BROOKLYN
LONG ISLAND SOUND
LONG ISLAND
Hudson R.
RARITAN BAY
ALLENTOWN
READING
HARRISBURG
Susquehanna R.
LANCASTER
Schuylkill R.
Delaware R.
TRENTON
PHILADELPHIA
CAMDEN
WILMINGTON
MARYLAND
WESTMINSTER
FREDERICK
BALTIMORE
CHESTERTOWN
ANNAPOLIS
DOVER
DELAWARE
DELAWARE BAY
LEESBURG
WASHINGTON
CHESAPEAKE BAY
Potomac R.
WEST VIRGINIA
VIRGINIA
CULPEPER
ORANGE
CHARLOTTESVILLE
RICHMOND
LYNCHBURG
PETERSBURG
ROANOKE
James R.
EMPORIA
HOUSTON
ALBEMARLE SOUND
NORTH CAROLINA
WINSTON
DURHAM
RALEIGH
PAMLICO SOUND
WADESBORO
Cape Fear R.
LANCASTER
BENNETTSVILLE
SOUTH CAROLINA
WINNSBORO
COLUMBIA
Pedee R.
EDGEFIELD
AUGUSTA
Santee R.
ATLANTIC OCEAN

FIG. 1.—Map of the Middle and Southern Atlantic States, showing the location and extent of the regions discussed in this bulletin. The Coastal Plain is shown on the map by continuous lines, the inland boundary being to some extent arbitrary. The region between the Coastal Plain and the approximate course of the 500-foot contour is shown by broken lines.

TOPOGRAPHY AND ELEVATION.

The topography of the Coastal Plain is unmarked by any special characteristics. The surface is generally level, rising slightly and gradually from the coast westward. A large number of rivers and smaller streams and their tributaries traverse the region in their course to the sea. They constitute an important factor in the soil drainage.

The elevation above sea level is comparatively slight, a large proportion of the region being less than 100 feet. Most of the remaining portions have considerably less than 200 feet elevation.

While the relative and actual elevations are practically identical and only a few feet, comparatively, above sea level, the character of the soil and subsoil and the natural water drainage provided by the streams which flow through this region insure as a rule good soil drainage. The atmospheric drainage is not so perfect as it is in regions where there is an alternation of ridges and valleys with considerable differences in relative elevations.

SOIL.

While several types of soil are represented in the Coastal Plain, the extreme characteristics of the different types which need to be considered in the present connection are not wide in so far as they have a bearing on commercial orcharding. In fact, it is evident that the influence of different methods of management in orchards located on the same type of soil could be made to exert decidedly more influence upon the behavior of varieties than would any inherent differences in the types themselves.

A large proportion of the soil is a light sand to sandy loam. The subsoil underlying much of this is of the same general character as the surface. In places, the subsoil is slightly heavier, having a small content of clay.

Small areas exist where there is sufficient clay in the surface to make a light clay loam, but it is very easily pulverized when cultivated. The subsoil of this is also heavier than that underlying the lighter types, but it is not compact. Small sections having this type of soil contain more or less gravel, from a quarter of an inch to an inch in diameter. This soil is somewhat "stronger" than the more sandy types.

Several other types might be distinguished by drawing very fine distinctions, but it is sufficient for the present purpose to consider them as variations of those already mentioned. Generally speaking, the soil is free from rocks and is easily worked.

The characteristics of the subsoil which have been described are known to extend to a great depth in many instances, as shown by wells and other excavations.

While these soils may not contain as large a supply of reserve plant food as some other types they are generally productive. Their physical properties are such as to favor deep penetration by the roots of growing plants, thus giving the plants a relatively large feeding area. The soil also responds readily to the application of commercial plant foods. It may be said in comparison with the average growth made by trees in other apple-growing sections that in the more important sections of this region they develop a good amount of wood growth and are relatively long lived.

The capillarity of the soil is strong, and the character of the subsoil makes it a deep reservoir for the storing of moisture. While this may pass off readily through surface evaporation under some conditions, it can be largely conserved by thorough cultivation. It is seldom that crops suffer more from lack of moisture here, under proper management, than in other sections having a similar amount of precipitation but more compact types of soil.

CLIMATE.

The climate of a place affects the plant life growing therein in many ways. In some one or more of its elements it is the most potent determinant of plant growth. Climate is an exceedingly complex influence, and the numerous combinations of the factors which constitute it render its effect upon plant life difficult in the extreme to interpret.

Each of these factors, as it is manifested in the climate of a place, acts in a particular way upon the varieties of apples, as of other forms of plant life, which may be grown there. The manner in which a variety responds to the influence of these factors, singly or in combination with one another, determines what the effect of the climate is upon that variety, and therefore its relative adaptability to particular purposes in that region so far as the climatic factor is concerned.

In its influence upon vegetation of all kinds, climate may be resolved into a number of elements of which the following are the most important:[a]

(1) Precipitation (rain and snow).
(2) Temperature (from day to day, and the mean).
(3) Extremes of heat and cold.
(4) Time and frequency of frost.
(5) Amount and intensity of sunshine.
(6) Humidity and transparency of the atmosphere.
(7) Direction and velocity of wind.
(8) Perhaps the electrification of the atmosphere.

It will thus be seen that climate is more than a matter of temperature and moisture, as popularly applied, though these factors are doubtless the most potent of any in their effects upon plant growth. It is not intended, however, within the limits of this paper to discuss at length what these effects are, even if it were possible to do so. There is an unfortunate lack of adequate means for measuring some of these elements, which doubtless are of great importance, and of interpreting them in terms of their influence upon plant life. Records of precipitation and temperature are abundant, but they seldom represent actual orchard conditions, being taken usually at points more or less distant from fruit plantations and often with instruments attached to buildings many feet above the surface of the ground. This is true, at least, of many of the records which are continuous for any considerable period of time.

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[a] See Encyclopedia Americana, under "Climate."

In general it may be stated that in order for a plant or a variety to succeed without irrigation there must be sufficient precipitation to maintain growth adequate to the end for which the plant is intended. As regards temperature, the extremes must be within certain more or less definite limits, and the mean, especially for the more critical periods in the life of the plant, must accord with the particular requirements of each individual. The mere matter of late spring frosts—an unfavorable extreme at a critical period—may indicate the impossibility of successfully growing certain fruits in some localities.

As applied to the region now being considered, it is sufficient to state that with certain general exceptions, noted elsewhere, the climatic conditions are favorable for the cultivation of early apples in most sections of the region. The orchards now in bearing testify to this fact. The extremes of temperature in most parts of the region are not severe, the precipitation is usually sufficient to meet the requirements, and the other climatic factors in most sections are equally favorable to the end in view.

The following tables, taken from the Monthly Weather Review for the years 1902 to 1907, inclusive, are composed of climatological records at three different stations located respectively in the southern, central, and northern sections of this region. They represent to some extent the climatic conditions which prevailed during the years mentioned and furnish one of the best available means for comparing the climate of this region with that of other sections where similar data are to be had. Such a comparison should assist in correctly forecasting for other sections the behavior of the varieties considered, so far as the climatic factors are concerned. These climatological data are also inserted for use in connection with the phenological records that appear on later pages.

As will be noted, the following table gives the monthly maximum, minimum, and mean temperatures and the precipitation. The geographical arrangement of the stations as they appear in the tables is from south to north.

TABLE I.—*Records of temperature and precipitation for Kinston, N. C., Seaford, Del., and Moorestown, N. J., for the years 1902 to 1907, inclusive.*

Place and month.	1902.				1903.			
	Temperature.			Precipitation.	Temperature.			Precipitation.
	Maximum.	Minimum.	Mean.		Maximum.	Minimum.	Mean.	
Kinston, N. C., elevation, 46 feet. (United States Geological Survey):	*°F.*	*°F.*	*°F.*	*Inches.*	*°F.*	*°F.*	*°F.*	*Inches.*
January	73	15	41.3	1.01	71	18	43.0	2.96
February	76	19	38.4	6.70	74	16	48.4	5.91
March	83	22	54.9	3.04	81	34	60.0	8.05
April	89	30	61.2	2.34	86	30	56.7	2.99
May	97	44	72.8	2.64	95	45	67.6	3.91
June	100	50	77.5	3.92	90	51	....	....
July	104	60	82.6	2.69	97	60	79.4	8.07
August	99	52	78.6	8.91	97	62	79.6	6.93
September	91	46	72.6	2.76	88	41	71.5	.89
October	84	31	62.9	5.13	86	27	57.4	3.28
November	81	31	57.2	4.14	71	14	....	.60
December	71	16	45.5	1.82	61	15	36.2	1.99
	....	....	....	45.10	....	....	....	[a] 45.58
	1904.				1905.			
January	67	10	35.6	4.12	76	11	40.2	0.85
February	75	17	38.2	4.10	65	15	38.1	5.06
March	79	27	51.8	5.04	88	25	56.6	2.52
April	88	28	58.6	.82	90	29	61.2	4.06
May	93	43	68.8	3.78	92	49	73.0	5.57
June	99	51	77.6	1.29	96	49	77.2	3.90
July	101	62	80.4	5.00	98	62	79.4	4.38
August	98	57	78.2	3.58	99	53	77.2	4.22
September	90	44	71.6	4.75	96	45	74.2	1.70
October	86	33	59.7	1.73	92	33	62.4	3.12
November	72	24	48.6	2.30	80	23	52.1	1.58
December	69	20	41.0	2.82	70	20	45.2	4.75
	....	....	....	39.33	....	....	....	41.71
	1906.				1907.			
January	79	21	48.0	3.68	80	17	51.4	1.13
February	74	17	44.1	4.63	72	9	42.6	2.39
March	80	22	50.4	7.53	98	25	59.2	2.39
April	94	30	63.8	.52	83	28	54.6	4.05
May	98	37	70.0	3.41	95	40	68.7	5.56
June	100	61	78.8	4.37	98	49	73.4	9.07
July	100	64	79.2	9.16	102	58	81.3	9.11
August	96	67	81.5	13.08	96	58	78.6	5.02
September	96	57	78.0	.59	97	51	77.0	3.83
October	87	28	64.4	4.13	93	29	59.0	.89
November	85	22	52.3	.84	79	25	51.2	3.19
December	77	17	46.7	1.34	79	19	46.0	3.08
	....	....	....	53.28	....	....	....	49.71

[a] This total covers eleven months only.

TABLE I.—*Records of temperature and precipitation for Kinston, N. C., Seaford, Del., and Moorestown, N. J., for the years 1902 to 1907, inclusive*—Continued.

Place and month.	1902.				1903.			
	Temperature.			Precipitation.	Temperature.			Precipitation.
	Maximum.	Minimum.	Mean.		Maximum.	Minimum.	Mean.	
Seaford, Del., elevation, 40 feet. (Estimated):	°*F.*	°*F.*	°*F.*	*Inches.*	°*F.*	°*F.*	°*F.*	*Inches.*
January	52	12	32.0	3.73	56	12	34.3	3.46
February	62	8	30.0	5.01	69	6	38.4	6.90
March	75	20	47.1	2.98	76	25	51.1	5.67
April	87	31	53.5	3.79	86	28	52.6	3.98
May	88	40	64.6	2.29	91	37	64.6	2.51
June	96	50	72.8	6.86	88	50	66.6	3.46
July	100	57	78.1	5.55	100	52	76.0	3.91
August	93	52	73.8	1.69	96	56	73.4	4.38
September	89	45	68.6	5.91	89	37	67.5	4.15
October	79	31	60.2	4.23	83	32	57.5	8.44
November	74	30	53.2	3.16	79	17	42.6	1.71
December	63	17	37.0	4.79	54	11	31.8	3.70
	....	....	....	49.99	....	....	....	52.27
	1904.				1905.			
January	62	2	29.2	1.73	60	− 4	29.8	4.48
February	59	3	28.5	2.32	50	− 2	26.8	3.83
March	68	19	41.2	3.39	77	19	44.8	2.20
April	77	26	48.4	1.95	81	27	62.2	2.89
May	82	41	62.2	1.52	82	40	63.4	5.50
June	94	44	69.5	2.02	89	45	69.2	4.02
July	94	54	73.5	7.74	95	57	74.4	6.73
August	88	49	71.4	1.32	89	53	72.2	5.69
September	90	35	66.6	2.08	82	40	66.7	6.19
October	83	29	52.6	2.73	80	31	57.0	1.45
November	66	21	42.4	2.01	72	16	44.6	.66
December	60	2	30.4	6.07	62	17	38.3	4.58
	....	....	....	34.88	....	....	....	48.22
	1906.				1907.			
January	73	7	40.7	2.53	71	8	37.8	2.53
February	60	9	34.8	4.61	54	5	29.4	2.60
March	61	15	38.4	5.88	88	19	46.6	2.72
April	84	27	53.0	1.44	79	23	47.1	3.90
May	92	33	63.0	4.86	84	36	58.0	6.97
June	92	55	71.4	12.30	87	46	65.0	4.50
July	89	57	73.2	11.56	91	55	74.8	3.92
August	91	64	75.6	7.86	91	52	71.8	2.46
September	91	51	70.8	2.28	90	40	69.1	3.95
October	76	30	57.0	4.70	76	30	51.7	3.06
November	68	27	45.4	1.45	64	28	45.4	5.62
December	62	12	37.5	3.45	62	20	39.3	3.65
	....	....	....	62.92	....	....	....	45.88

TABLE I.—*Records of temperature and precipitation for Kinston, N. C., Seaford, Del., and Moorestown, N. J., for the years 1902 to 1907, inclusive*—Continued.

Place and month.	1902.				1903.			
	Temperature.			Precipitation.	Temperature.			Precipitation.
	Maximum.	Minimum.	Mean.		Maximum.	Minimum.	Mean.	
Moorestown, N. J., elevation, 71 feet. (Weather Bureau):	°*F.*	°*F.*	°*F.*	*Inches.*	°*F.*	°*F.*	°*F.*	*Inches.*
January	53	11	29.8	2.95	53	9	31.8	3.69
February	57	9	28.0	6.45	68	0	34.6	4.71
March	75	19	45.3	4.22	76	24	48.8	5.28
April	87	31	51.4	3.63	90	28	51.6	5.33
May	87	38	61.2	2.45	93	31	64.2	.44
June	91	48	68.3	7.30	85	45	65.0	5.65
July	92	55	73.6	7.05	94	50	73.4	5.44
August	88	49	70.6	8.44	92	49	69.2	5.49
September	87	43	65.4	5.29	88	36	65.8	4.42
October	76	27	56.7	7.59	80	31	57.0	8.79
November	76	27	50.4	2.50	73	14	41.4	1.18
December	60	12	32.9	7.34	54	9	30.0	4.48
	....	....	....	65.21	....	....	....	54.90
	1904.				1905.			
January	56	−9	24.0	3.02	54	0	27.7	2.87
February	59	0	25.6	2.40	45	−1	24.2	2.79
March	68	15	38.4	3.83	81	9	41.0	4.24
April	79	25	48.2	2.61	80	26	50.8	3.12
May	92	40	63.6	3.23	84	34	62.2	1.31
June	94	46	69.0	3.07	91	45	68.9	2.93
July	92	52	72.4	5.69	96	55	75.2	2.85
August	89	48	71.1	7.08	90	50	71.6	5.66
September	88	32	65.8	5.84	84	37	66.0	3.81
October	84	25	52.6	4.00	87	29	56.3	3.84
November	63	18	40.9	2.04	67	15	42.7	1.87
December	53	1	27.0	2.93	61	15	36.6	3.59
	....	....	....	45.74	....	....	....	38.88
	1906.				1907.			
January	72	5	37.2	2.85	67	0	32.6	2.93
February	61	4	32.2	2.06	48	0	24.1	2.86
March	58	13	35.4	5.37	86	11	42.0	2.66
April	81	26	52.4	2.71	79	23	46.0	3.68
May	90	35	62.1	2.66	85	32	55.8	5.34
June	92	48	71.5	7.33	91	41	64.8	6.85
July	90	53	73.8	4.11	90	53	73.3	4.45
August	92	62	75.2	9.43	90	51	69.8	6.48
September	89	45	69.2	3.99	88	39	67.4	6.74
October	75	29	55.1	4.20	76	26	50.8	3.89
November	68	22	44.2	1.70	62	21	43.8	5.49
December	65	8	34.2	3.34	62	17	37.2	4.25
	....	....	....	49.75	....	....	....	55.62

The following data regarding the occurrence of spring frosts at various points in this region are of particular value when considered with the blossoming dates that constitute a part of the phenological data given on later pages. These data have been furnished by the United States Weather Bureau.

TABLE II.—*Average dates of the latest spring frosts at different localities in the Middle Atlantic States.*

Location.	Average date of latest frost.	Date of latest frost recorded.	Number of years recorded.
Central and Southern New Jersey:			
Asbury Park	Apr. 19	May 29	11
Moorestown	Apr. 23	May 15	41
Vineland	Apr. 17	May 22	36
Atlantic City	Apr. 11	Apr. 25	20
Chesapeake peninsula:			
Chestertown, Md	Apr. 19	May 11	10
Easton, Md	Apr. 12	Apr. 28	11
Millsboro, Del	Apr. 17	Apr. 30	14
Princess Anne, Md	Apr. 23	May 12	10
Maryland, west of Chesapeake Bay:			
Baltimore	Apr. 4	May 3	33
Laurel	Apr. 21	May 11	10
College Park	Apr. 29	May 12	10
Solomons	Apr. 8	Apr. 27	11
District of Columbia:			
Washington	Apr. 7	May 11	37
Virginia:			
Warsaw	Apr. 14	Apr. 28	11
Hampton	Mar. 27	Apr. 6	11
Norfolk	do	Apr. 26	33

THE SUMMER-APPLE INDUSTRY OF THIS REGION.

DEVELOPMENT.

In the sections of this region where there now exist large summer-apple interests, there were formerly very extensive peach orchards. The summer-apple industry, as a commercial feature, has been developed largely since the destruction of many of the peach orchards by yellows. In fact, apple culture has to some extent taken the place of peach growing, many apple orchards now occupying land formerly devoted to peaches.

Some of the United States census figures relating to the peach interests of Delaware and New Jersey are of interest in this connection. Unfortunately these figures are not given in sufficient detail prior to the census for 1890 to admit of any comparison, but those for the year named and for 1900 stating the number of peach trees of bearing age in the States mentioned show the trend during that decade, as follows:

	1890.	1900.
Delaware	4,521,623	2,441,650
New Jersey	4,413,568	2,746,607

Similar data for Kent County, Del., are also suggestive, since very heavy plantings of peaches formerly existed in this county, and at the present time it is the center of the most extensive summer-apple interests of any section in this region.

Census data relating to apples in this section are of little significance, as they include the trees of bearing age of all seasons of ripening, and many fall and winter sorts are grown as well as summer varieties, yet the recent extension of apple culture, especially in Kent County, Del., has been quite largely of early varieties. Data regarding the number of peach and apple trees of bearing age in this county are therefore of interest for comparison with the data as to peach trees just presented, as follows:

	1890.	1900.
Peach trees	2, 335, 740	824, 430
Apple trees	114, 371	186, 457

The period of most rapid extension of the early-apple interests, however, has been during the past eight or ten years; hence, it is not shown in any available census figures.

PRESENT STATUS AND EXTENT.

A general statement as to the distribution of the orchards in this region, giving the more important centers of early-apple production, will give the reader some conception of the extent and importance of this phase of fruit culture.

In New Jersey, the principal early-apple interests are within a radius of 18 to 20 miles of Philadelphia. Large quantities of fruit are grown in this section, nearly all of which is hauled in wagons to the Philadelphia markets. A common type of wagon used for this purpose is shown in Plate II, figure 1.

There are numerous other orchards in central and southern New Jersey in which early apples are an important factor, but they are considerably isolated in their location with regard to one another, and the fruit from them is handled quite differently from that which is grown near Philadelphia.

In Delaware the important section is the central part of the State, the commercial orchards being well distributed over Kent County within a distance of 8 or 10 miles of the railroad.

In the other sections of Delaware, and in the Maryland, Virginia, and North Carolina sections of this region, early apples are grown in much the same way that they are in southern New Jersey. Family orchards and many gardens contain such varieties, and occasionally isolated orchards of commercial size are to be found, but the industry is not centralized in particular sections, though in the aggregate the amount of fruit grown is considerable.

In the sections of this region where the fruit interests have already been well developed a good system of orchard management is generally practiced. However, in many of the other sections, where fruit growing at present is only a secondary matter, the orchards are generally greatly neglected. Little or no cultivation is given, unless in connection with the growing of interplanted crops; usually no pruning and no spraying. Under these conditions many of the orchards are sorely attacked by insects and fungous diseases. There is no reason to suppose, however, that these difficulties may not be readily overcome by the application of the usual methods in such cases.

With relation to the last statement, however, it should be noted that in the southern section of this region certain fungous diseases of the apple appear to be unusually prevalent, and should any extensive commercial development of apple culture be considered, this feature should have full consideration. However, while the climatic conditions may have some influence in the extent to which these diseases have appeared in the past, it is not assumed that the more common diseases which are now noticeable could not be readily controlled by the use of certain precautions and the application of proper spray mixtures. In fact, a few orchards in this section which have been properly attended to demonstrate that this is the case, especially when varieties adapted to the region are planted.

NATURAL ADVANTAGES AND POSSIBILITIES OF THIS REGION FOR SUMMER-APPLE PRODUCTION.

The extent to which successful summer-apple culture in certain sections of New Jersey and the Chesapeake peninsula has been developed is good evidence of the natural advantages of these sections, but some of the other sections require notice in this connection.

Earliness of maturity is an important consideration, and the light sandy and sandy loam soils, which are characteristic of nearly the entire region, doubtless contribute toward this end. The temperature is usually relatively high during the period when the fruit is making its growth, without which the other factors, however favorable, would fail to produce early ripening.

The location of the region with reference to the larger markets and distributing centers of the East is likewise a favorable factor. The relationship between the points of production and distribution is always an important matter, and especially so in the handling of any quickly perishable product. In case there should be developed in the future a demand in the foreign markets for early apples, the comparatively close proximity of a large portion of this region to the eastern seaports, and the readiness with which the fruit grown therein could be landed on the docks, renders this region particularly adapted from this point of view for the supplying of such demands. Shipping facilities are likewise good. Many points in this region have access both to rail and water transportation, a condition always considered favorable to the fruit grower.

In general, the climatic conditions are favorable for the end in view. The only exceptions that call for special notice are the late spring frosts and cold periods following unseasonably high temperatures in winter, during which the fruit buds advance to a tender stage. If these unfavorable temperatures occur during the blossoming period, serious damage is likely to result. On account of the low elevation of this region it is more subject to these conditions than regions having higher relative altitudes. In selecting orchard locations, places where late spring frosts are known to occur to a serious extent should be avoided.

GROWING THE FRUIT.

As the subject-matter of this bulletin is primarily a description of the conditions that prevail in the Coastal Plain region and an account of the different varieties of early apples grown therein and their behavior, only passing mention is made of cultural and fruit-handling methods.

In general, it may be said that the orchard management requisite for the production of this class of fruit does not differ materially from the usual methods employed in growing winter apples. The same pruning, cultivating, fertilizing, spraying, etc., are required in the one case as in the other. The later sprayings commonly recommended for late varieties are not so necessary for the earlier sorts for obvious reasons, though the early applications should be made with the same thoroughness that is required for winter sorts. It is a question worthy of consideration, however, whether later applications made after the fruit has been harvested would not be worth while, at least in the case of varieties especially susceptible to fungous diseases, in order to protect the foliage during the long period between harvesting and the end of the season. The vigor and healthfulness of the trees might thus be insured and the crop the following season perhaps improved thereby.

HANDLING THE FRUIT.

METHODS AND CONDITIONS.

The methods employed in handling early apples are much more closely allied to those used in marketing peaches than to the usual manner of caring for winter varieties. This results naturally from the character of the fruit.

As a rule the fruit is intended for immediate consumption and is not usually marketed until fully ripe, or, at least, in suitable condition to use without delay. As its period of duration is short when edible maturity is reached, it must of necessity be used within a comparatively few days after it is put on the market. Some varieties, however, intended only for cooking, are shipped as soon as they are large enough for this purpose, without much regard to the degree of maturity which they may have reached. Although such varieties may be held longer than those marketed in a thoroughly ripened condition, they soon begin to deteriorate if held for any considerable length of time.

HARVESTING.

In harvesting early apples careful hand picking is practiced by a majority of the most successful growers. A few firm-fleshed varieties, the fruit of which ripens irregularly and drops as soon as it is well colored and fully ripe, are sometimes allowed to drop their fruit. If there is danger of the apples being bruised by striking the ground, a heavy mulch of straw is spread beneath the trees. But many of the most particular growers prefer to hand pick even these sorts, though it is rather laborious to do so on account of the ripe fruits being much scattered over the trees.

Some of the less exacting growers shake the fruit from the trees or beat it off with poles, claiming that the difference in price between the carefully handled fruit and the fruit handled by their method is not enough to justify the extra expense of hand picking. It should be noted, however, in this connection, that careless or rough handling of fruit in harvesting often accompanies indifferent methods of culture. The grade of the fruit grown frequently determines the expense that is justifiable in preparing it for market.

The period of growth from blossoming to maturity is relatively short, and the changes which occur in the development of the fruit take place with corresponding rapidity. It may be only a very short time, as measured by days, between a date when an apple is too immature to pick and the period when it becomes overripe. Because of this, several pickings of most varieties are usually made, as in picking peaches. The specimens which are small and immature when the first picking is made will commonly develop with increased rapidity, attaining a degree of perfection not reached by the more advanced specimens.

GRADING AND PACKING.

In the marketing of early apples the details of grading and packing require the same painstaking attention that the successful marketing of other quickly perishable fruits demand. Fruit that is bruised should be discarded. Though it may not appear to be defective when it is packed, bruises and other similar blemishes, especially in case of certain varieties, become very conspicuous after the fruit has been picked a short time. Even if it looks well when packed, such fruit is likely to deteriorate greatly before it reaches the market.

Some of the early apples grown in this region are prepared for market in the orchards, but most of them are taken to packing houses, where they can be more conveniently handled. Plate III, figure 1, shows a convenient packing house. The upper portion of the building is used for storing packages, etc. There is a door on each side, thus making it convenient to receive or discharge fruit at any point on the floor. A common method of handling early apples in the packing houses in grading and packing is shown in Plate III, figure 2.

PACKAGES.

Several different styles of packages are used in this region for early apples, of which the following are the most important. In some sections the ⅞-bushel crate, formerly much used in Delaware for shipping peaches, was commonly used in the earlier years and is still seen occasionally, though it has passed out of general use.

The growers in the New Jersey section who market their fruit in Philadelphia use the half-bushel peach basket, usually without covers. These are shown in Plate II, figure 1. In other important sections a ⅞-bushel basket with cover has been used for several years with excellent satisfaction. These baskets may be seen on the wagon shown in Plate II, figure 2. This figure also shows the manner in which these packages are loaded for hauling to the shipping station.

A few growers pack their fancy fruit in six-basket carriers and find that for some markets it pays to incur the additional expense which this style of package makes necessary. Twenty-pound Climax baskets are also used occasionally.

METHODS OF SELLING THE FRUIT.

Several methods of selling the early apples grown in this region are practiced. Perhaps the most simple one is that employed by the growers who are located in the New Jersey section within 15 to 20 miles of Philadelphia. The fruit is packed in half-bushel baskets as above mentioned, loaded on large wagons built for the purpose (Pl. II, fig. 1), and hauled directly to the commission houses or other markets. In some cases the grower runs his own stand in the market, perhaps handling truck and other farm produce at the same time. By either of these methods the packages are returned to the grower.

At the more important shipping centers the growers sell f. o. b. as much as possible, thus avoiding all risk in transit and the possibility of loss from poor market conditions. This method makes it possible to ship in car lots, as the buyer fills his cars ordinarily with fruit purchased of different growers.

MARKETS AND THE PLACE HELD BY SUMMER APPLES.

Very naturally, large and relatively near-by distributing centers, such as Philadelphia and New York, receive large quantities of summer apples from this region. To a less extent, some of the New England markets, principally Providence, R. I., and Boston, Mass., receive more or less fruit, especially of certain varieties. During the past few years, however, new and more distant markets have been sought. As a result, considerable quantities of fruit from the Chesapeake peninsula section are shipped to such points as Pittsburg, Pa.; Cincinnati, Ohio; Detroit, Mich.; Chicago, Ill.; and to even other more distant western and northwestern points.

Foreign markets also offer an outlet for considerable quantities of early apples, especially when the European crop is light. The results of the experimental export shipments made by the Bureau of Plant Industry indicate that for fruit of good grade properly handled and when the markets are not overstocked with home-grown fruit, good returns may be expected from London, Liverpool, and some of the other leading foreign markets.

As an important commercial product, summer apples are a comparatively new commodity in many markets and their use has been limited. They have not filled a place comparable with that held by peaches, winter apples, and some other fruits. Hence, in the past the period of real demand for them has usually been during a scarcity of other fruits. There is evidence, however, that a very large number of consumers have now come to think of summer apples as filling a definite place in their food supply. While the demand is naturally more or less influenced by the abundance of other fruit in the markets during the summer-apple season, it is not so much dependent upon the availability of other fruit as in the earlier years and it is becoming more constant as the regularity and abundance of the supply of early apples increases.

THE PROBLEM OF VARIETIES.

CONSIDERATIONS GOVERNING SELECTION.

There are several fundamental features which should always be considered in selecting the varieties of any kind of fruit to be grown in a given region or under particular conditions. The purpose for which it is to be grown, whether dessert or cooking, home consumption or market, should be given due weight. A variety may behave in a certain manner, ripen its fruit during a particular period, and show other habitual characteristics when growing under a certain combination of conditions of soil, climate, elevation, and cultural methods. When the variety is grown under other combinations of conditions it may behave in a very different manner. In other words, a variety is subject to the influence of the conditions under which it is grown. In those conditions there may be involved both natural factors, such as soil and climate, and factors which are more or less artificial, such as are imposed by man in his methods of culture.

It will now be understood how the subject-matter of the preceding pages has application to the notes which follow regarding the varieties that are being grown in this region. The fact is here emphasized that the statements made in the following discussion of varieties have specific application only to the fruit grown under the conditions that prevail in this region. It is hoped, however, that the information presented regarding existing conditions, and the behavior of the varieties referred to under those conditions, may be of some assistance in selecting varieties for other localities.

In the scope of this bulletin it has been the intention to include only varieties which reach maturity in some section of this region not later than the middle of September.

DISCUSSION OF IMPORTANT VARIETIES.

The following varietal list includes the most important early varieties which are grown in this region, and a considerable number of others which are known only in a limited way. No attempt, except in a few cases, has been made to give a detailed description of the varieties mentioned. Usually a few of the more prominent varietal characteristics are named in order that the reader who is unacquainted with a variety may be able to obtain readily a general idea of its appearance and quality.

Alexander.

This is a very old variety, probably of Russian origin. Its history is briefly indicated in the following:

> "The evidence is reliable that Red Astrachan, with Duchess of Oldenburg [Oldenburg] and Alexander, were introduced into England by the Royal Horticultural Society from Sweden, as Russian apples about the year 1816. Wm. Kenrick in his catalogue in 1832 speaks of them as promising. In 1834 The Massachusetts Horticultural Society imported them, adding Tetofsky [Tetofski]. In 1839 the elder Manning of Salem exhibited them as home grown. Since then they have been widely distributed." [a]

The Alexander apple has become quite widely distributed in many parts of the country, though not grown in large quantities. In this region a few trees of it have been found at widely separated points. The tree is a fairly strong grower on the light soil where it has been observed. It comes into bearing quite young, but fruits mostly on alternate years. The fruit is roundish conic; usually large to very large; greenish yellow, heavily striped with red when well colored; acid; quality good; of value primarily for cooking. Its season begins the last of June in eastern North

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[a] Letter of Mr. William C. Strong, Waban, Mass., April 2, 1906.

Carolina; in central New Jersey, about one month later. The variety is considered desirable as a commercial sort by some of the growers. In some sections the fruit is inclined to drop prematurely, but this characteristic has not been reported from this region in the present connection.

Bachelor Blush.

This variety is said to be of New Jersey origin, but details of its history are not obtainable. It is not widely disseminated and in this region is known only to a very small number of growers. The rather meager information obtainable concerning its behavior indicates that it may possess considerable merit.

The tree is said to be prolific, bearing more or less fruit annually. The fruit resembles the Maiden Blush apple considerably but is rather larger than that variety; frequently more highly colored and of better dessert quality. In central New Jersey ripening begins the last of August.

Benoni.

This variety originated in Massachusetts many years ago. The first published reference to it appeared in the New England Farmer in 1831. It is growing in a few orchards in central New Jersey and in at least one tide-water orchard in Virginia.

The tree grows with sufficient vigor and bears heavy crops on alternate years, though under some conditions nearly annual crops are produced. The fruit possesses high dessert quality and is of attractive appearance; color yellowish, overspread with red and striped with crimson. It is too small, however, for general commercial purposes, though for a special trade some demand might be created for it on account of its high dessert quality. This also commends it for home use.

In the Virginia orchard, above mentioned, which is located in close proximity to the coast, this variety has done especially well in recent years. The trees bear heavily and the fruit reaches a good size for the variety, obtaining a high degree of perfection. In this orchard good cultural conditions are maintained. The fruit begins ripening early in July in Virginia; in central New Jersey it is two weeks or so later.

Bibbing.

So far as information at present available indicates, this variety was first propagated and distributed in this region sometime prior to 1875, by the late Mr. Randolph Peters, whose nursery was not far from Wilmington, Del. It does not appear, however, to have been planted extensively, as only an occasional orchard in this region now contains it. On account of its very close resemblance to the Oldenburg apple, and the danger of confusion with that variety, attention is here directed to it.

In habit of growth, the tree makes a rather flat, broad top, moderately dense, and with heavy dark-green foliage. In contrast with this habit the top of Oldenburg is usually more roundish and less dense and the foliage somewhat lighter. The fruit of these two varieties is hardly distinguishable one from the other. Bibbing is perhaps less sharply acid and may be slightly earlier than Oldenburg. Otherwise it is scarcely possible to distinguish any constant points of difference between them, and even those noted as distinguishable may be so influenced by conditions as to be of little value for purposes of identification.

Bietigheimer. Synonym: *Red Bietigheimer.*

This variety is of German origin. It is growing in a small number of orchards in central New Jersey and Delaware, both on the very light sandy soils and the more loamy types.

The tree is a fairly vigorous, upright grower under these conditions, but the variety is not proving thus far to be of any special value. It is late in coming into bearing, trees 10 to 15 years old having borne very sparingly. Older trees in other regions indicate that heavy bearing is unusual. Under favorable conditions the fruit is very large in size; skin yellowish, nearly covered with a pinkish-red blush, often with a more or less marbled effect; subacid in flavor. The fruit thus far produced in this region has been rather inferior in appearance and quality. Its season in New Jersey and Delaware begins the last of July to the first of August.

Bonum. Synonym: *Magnum Bonum.*

The Bonum apple is supposed to have originated in Davidson County, N. C., and has been in cultivation many years. It is quite widely distributed throughout the South. In this region it is growing in many places in North Carolina, largely in the older orchards, and to some extent in Virginia. It is rarely found at more northern points.

The tree is fairly vigorous and generally healthy, with dark heavy foliage. In the sections above mentioned, it is a regular bearer. The fruit is small to medium in size, occasionally large; its under color is yellow, overlaid with dark crimson; mild subacid flavor and of excellent dessert quality. In the sections referred to, its season begins early in September and continues through the greater part of October. It is even said by some growers that it can be kept all winter without special care.

For home use, a personal market, or even for general commercial purposes this variety appears to be worthy of more extensive planting in these sections. Indications point also to a range of adaptability extending as far north as central Delaware. The high dessert quality and fine appearance of the fruit make it particularly attractive. It is admirably suited for hotel or other trade where a highly colored apple of fine quality and not over large size is desired.

Bough. Synonym: *Sweet Bough, Large Yellow Bough.*

The first mentioned synonym is the name under which this variety is generally known, but it is reduced to Bough under the rules of nomenclature of the American Pomological Society. This is also the name under which it was described in 1817 by Coxe, this being the earliest published description. Its origin is obscure, except the mere fact that it is a native variety.

The Bough apple is widely distributed in many sections of the country, and in this region it is in many orchards throughout the Maryland, Delaware, and New Jersey sections, though not produced in large quantities.

The tree is only moderately vigorous under the conditions in these sections. Some complaint of its being short lived is made. A few instances of rather serious twig blight have been observed, but this does not appear to be common. Shy bearing is reported by some, but, as a rule, fairly regular and abundant crops are produced. The fruit is medium to large, greenish yellow, tender, crisp, and of a rich, sweet flavor. Its season usually lasts about two weeks in individual orchards, though occasionally the fruit is all harvested at a single picking. It may be had at some point in the sections mentioned during most of July, the exact date of maturity depending upon the location and local conditions.

Experiences differ as to the profitableness of this variety. Its principal use, on account of its flavor, is for eating out of hand or for baking. It is the one sweet early variety that is commonly grown, hence it may be of particular importance for this reason. It is probably better adapted to a special trade or a personal market than it is for general commercial purposes. It is said to sell well at some of the seashore resorts along the New Jersey and Delaware coast.

Buckingham. Synonyms: *Fall Queen, Equinetely, Byers' Red.* Nearly thirty other synonyms have been applied less generally than the ones here mentioned.

The history of this variety traces back with fairly definite records to 1777 to the garden of Col. John Byers, of revolutionary fame, who lived in Louisa County, Va. The Buckingham is quite widely distributed in many sections of the South, but is not grown in large quantities. It is in a few orchards in the Virginia and North Carolina sections of this region, but is relatively unimportant.

The tree in a large proportion of the orchards in these sections where it is found is a weak grower and more or less subject to certain diseases. The fruit, when well grown, is large; under color yellow, heavily washed over most of the surface with crimson and rather indistinctly striped; subacid, very pleasant; good to very good. In these sections its season begins early in September, but continues for several weeks so that it may be considered an early fall rather than a summer variety.

It is of doubtful value in the Virginia and North Carolina sections of this region. Even in the orchards where the trees are in good condition the fruit does not mature well and is apt to rot, indicating a lack of adaptability to these conditions. As the variety is well adapted to the conditions existing in the Piedmont and Blue Ridge regions of Virginia and North Carolina where the altitude is higher than in the Coastal Plain, it is possible that it would do relatively better in the northern portion of this region than it does in the southern.

Celestia.

This variety originated in Miami County, Ohio. The original tree is said to have been a seedling of Stillwater. It has been in cultivation for forty years or more though it has never come into general cultivation. It has been found in only two or three orchards in this region and in the adjacent areas. These are in Delaware and Virginia.

The tree is a fine, thrifty, upright grower and a prolific, nearly annual, bearer. Fruit large; roundish conical; pale yellow, moderately sprinkled with gray or brown dots; flavor rich, mild, subacid, very pleasant; quality very good. It reaches edible maturity in the Virginia location about the first of September and is slightly later farther north in the Chesapeake peninsula.

Though the trial of this variety in this region has not been sufficient to warrant definite conclusions, it is promising for its season and highly prized by the few growers who have had experience with it.

Champlain. Synonyms: *Nyack, Nyack Pippin.*

In this region this variety is known as Nyack or Nyack Pippin. It is supposed to have originated in Vermont or New York, but historical data are lacking. It is grown to a limited extent in some sections of the North, but is not generally known to fruit growers. It is in quite a large number of orchards in New Jersey and Delaware, but as in the North very many of the growers are unacquainted with it.

The tree is a fairly vigorous, somewhat upright grower, apparently long lived. It is generally productive, bearing nearly annual crops in some orchards. The fruit is medium to large; greenish yellow, sometimes with blush on exposed side when fully ripe; pleasant subacid flavor. It is usually shipped from these sections during the last week or ten days of July and early August. The fruit holds to the tree fairly well, so that it may be handled during a rather long period of time.

While of minor importance, relatively, in the sections of this region where it is grown, it is usually considered a desirable commercial variety, though perhaps less profitable than some other sorts.

Chenango. Synonyms: *Chenango Strawberry, Strawberry, Sherwood's Favorite.*

This variety probably originated in New York, though some accounts suggest Connecticut. It is grown sparingly in many sections of the North; in this region it is not being grown commercially and is to be found in but very few orchards.

The tree is fairly satisfactory in its habit of growth. Fruit is oblong, conic, above medium size; whitish yellow, striped and splashed with crimson; pleasant subacid; very good. In the New Jersey section the season begins about the first of August.

The locations where the variety has been reported are on light, sandy soil. It does not appear to be well adapted to this region. At one place in central New Jersey, under rather indifferent cultural conditions, the fruit is said to decay usually before it ripens, and it seldom, if ever, colors well. Besides this it does not develop properly. This has been the continuous record of trees which are from 35 to 40 years old. Younger trees in southern Delaware have perhaps been slightly more satisfactory, but it is apparently of little, if any, value here.

Colton. Synonym: *Early Colton.*

This variety is said to have originated in Franklin County, Mass., on the farm of a Mr. Colton. It has been propagated more or less for nearly seventy years usually under the synonym mentioned. It has some prominence in the Delaware and Maryland sections of this region, where it is grown more or less on the light sandy soils characteristic of these sections.

The tree is moderately vigorous, healthy, and fairly prolific, but in many instances, even under good care, the fruit fails to develop satisfactorily and many culls result. It bears with a good degree of regularity, producing some fruit nearly every year. The apple is of medium size, greenish yellow, sometimes blushed on exposed side, and of subacid flavor. The normal season of ripening in these sections is about the middle of July. The fruit is sometimes handled in a rather immature condition as early as the first week in July. It matures quite evenly, so that frequently the most of the crop can be gathered at a single picking.

In the experience of some growers, this variety is not as good for shipping as some other sorts, especially when marketed in a fully ripe condition. It is inclined to turn dark under the skin if bruised, rendering it unattractive in appearance. At present it is not of great value in this region and as there are one or two other more desirable varieties, especially Early Ripe, of nearly the same season, it is doubtful if it will become of any special importance here, though possessing some merit

Cornell. Synonyms: *Cornell's Fancy, Cornell's Favorite.*

The original tree of this variety is said to have stood on a farm owned by Mr. Gilman Cornell and situated in Southampton township, Bucks County, Pa. It is not much grown in this region, being confined mostly to a few orchards in the New Jersey section. Light sandy soils characterize the locations where it has been observed. Some complaint is made that the trees lack vigor and are short lived.

The fruit is medium size or above, much resembling Chenango, with which it is doubtless sometimes confused. It is of better dessert quality than that variety. It appears to be better adapted to the section above mentioned where it is being grown than Chenango, since it develops to a good degree of perfection without manifesting the defects referred to under that variety. It begins to ripen about the middle of August in central New Jersey.

Cross.

The Cross apple originated near Fair Play, Washington County, Md., but has not become widely known. So far as observed in this region, it is growing in only one orchard, which is located in Caroline County, Md.

The tree is a strong, vigorous grower and an abundant bearer. The fruit is large; roundish oblate; greenish yellow, striped and splashed with light red; slightly subacid; good to very good in dessert quality; also recommended for culinary purposes. In the section above mentioned it ripens from the middle to the last of August. It has not been sufficiently tested in this region to demonstrate its value, but is considered very promising for its season by the one grower interviewed who has it under observation.

There is a Russian variety grown under this name which is a late-keeping sort.

Dawes. Synonym: *Dawes Porter.*

Origin, Massachusetts. This variety is known only to one or two growers in this region, hence it has not been tested sufficiently to determine its value. It is a large apple; light yellow, shading to a darker color with a suggestion of red; mild subacid, rich; very good. It ripens during August in the central part of the Chesapeake peninsula.

Early Edward. Synonym: *Edward Early.*

Aside from the fact that this variety is of American origin, its history is obscure. It was mentioned by James Mease in the first American edition of "The Domestic Encyclopedia," which was published in Philadelphia in 1804. It is grown to a very limited extent, and in this region it is to be found in only a small number of the older orchards.

The tree is fairly vigorous and productive. Where the San Jose scale is a serious pest it appears to be peculiarly resistant to this insect. It has been observed that when certain other varieties are even destroyed by it, this one remains nearly free from attack. The fruit is of medium size or above; yellow, washed and striped with red and crimson; subacid, pleasant; very good in dessert quality. In the central and northern sections of this region, ripening occurs the last of July and the first of August. When fully ripe, rotting at the core is frequently serious. For this reason its value for market purposes is doubtful, but it may have a place for home use on account of its high dessert quality.

Early Harvest. Synonym: *Prince's Harvest.*

This apple was first mentioned in American pomological writings in 1806. It is therefore a very old variety and supposed to be of American origin. Few varieties have become so widely disseminated over a large portion of the country as this one. Throughout this region it is probably the most widely grown of any sort. However, it is to be found more generally in the older orchards, having been planted but little in recent years.

Generally the tree is fairly vigorous and healthy, though in some sections of this region, especially in the North Carolina portion, it is often badly affected with stem or trunk tumors or knots [a] and certain other fungous diseases. The fruit is, typically, medium to large in size; pale-yellow color; pleasant subacid flavor; dessert quality, very good. Ripening begins at southern points in this region by the middle of June; in the northern portion it is about three weeks later.

As ordinarily grown, the fruit is very irregular in size and grade, many poor, knotty specimens being produced. It is much subject to injury from the plum curculio. Hence a considerable proportion of the crop is usually of low grade, which renders it less profitable commercially than some other varieties of the same season. As a market sort, therefore, it is not popular. Its high dessert quality, however, gives it a place in the home orchard. It is probable that it is better adapted to the climatic conditions in the northern or New Jersey portion of this region than at southern points. Here the tree is generally less subject to disease and as a rule the fruit develops to a higher degree of perfection.

Early Joe.

This variety originated many years ago at East Bloomfield, Ontario County, N. Y., in the same orchard with Northern Spy and Melon. It is said to have received its name from the fact that a man by the name of Joe was for a time accustomed to steal the fruit early in the morning before he was in danger of being observed. It is not much cultivated in any section. In this region, it exists in only an occasional orchard. The trees which have been observed here are making a rather poor, unsatisfactory growth. The fruit is small to medium; oblate, conic; dull greenish-white undercolor, with dull red washing and striping; tender, juicy, mild subacid, and of high dessert quality. Its season in the central portion of this region is the last of July and early August. Its high quality commends it for home use, but it is too small for market purposes. On account of the weakness of the tree, however, it is of doubtful value in this region for any purpose.

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[a] See Circular 3, Bureau of Plant Industry, U. S. Dept. of Agriculture.

Early Ripe.

This variety is supposed to have come originally from Adams County, Pa., but the point is open to question. It is evidently not generally known over a wide range of country, but in this region it is one of the most important of the early commercial sorts of the white or yellow skinned varieties. It is grown extensively, however, only in the Chesapeake peninsula sections. There appears to be no well-defined reason why it has not become known and generally planted in New Jersey, but it is practically unknown in that section; the same is true in the Virginia section. In North Carolina it is to be found in a small number of orchards.

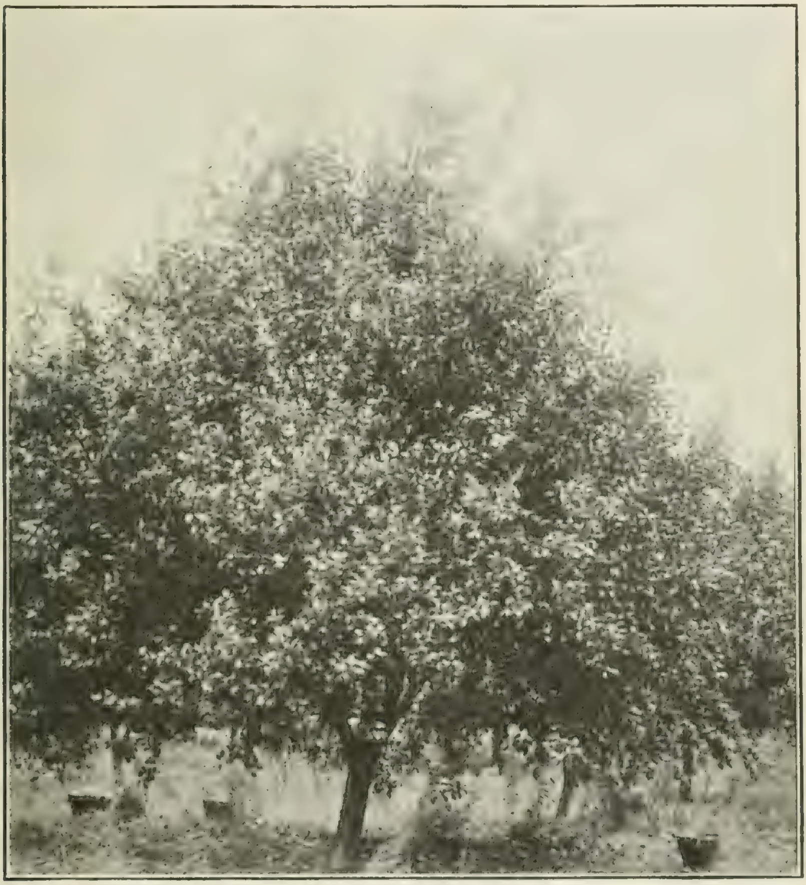

FIG. 2.—An Early Ripe apple tree in Delaware, about 15 years old.

The tree is rather upright in habit of growth, with strong tough limbs not easily broken. (Fig. 2.) It bears early and in most cases abundantly, with nearly annual crops. The fruit is medium or above in size, yellow, subacid, of firm texture, good quality, and less subject to insect injury, especially the plum curculio, than many other varieties.

In season it is one of the earliest. In some places it is the first variety to be shipped from the section where it is extensively grown. It cooks well before it is fully ripe, and this fact is often taken advantage of by the growers, who market it earlier, by a few days, than could otherwise be the case. The first pickings are often made in central Delaware during the last days of June; it is usually all marketed by the middle of July. In the North Carolina section it is about two weeks earlier. The fruit holds to the trees well, however, so that its market period, including the period of full maturity, is longer than that of most early sorts, extending over nearly a month, if desirable to hold the fruit that length of time. On the other hand, the fruit matures quite uniformly and it may generally all be gathered in two pickings if desired. Its texture remains firm when fully ripe; hence, it is possible to handle the fruit largely in accordance with market conditions. It appears probable that it would be a satisfactory variety for its season throughout the region. It has been planted extensively in recent years in the Chesapeake peninsula section instead of Early Harvest. In one or two instances, this variety has not given its accustomed satisfaction, being late in coming into bearing and otherwise faulty. Such experiences, however, are exceptional.

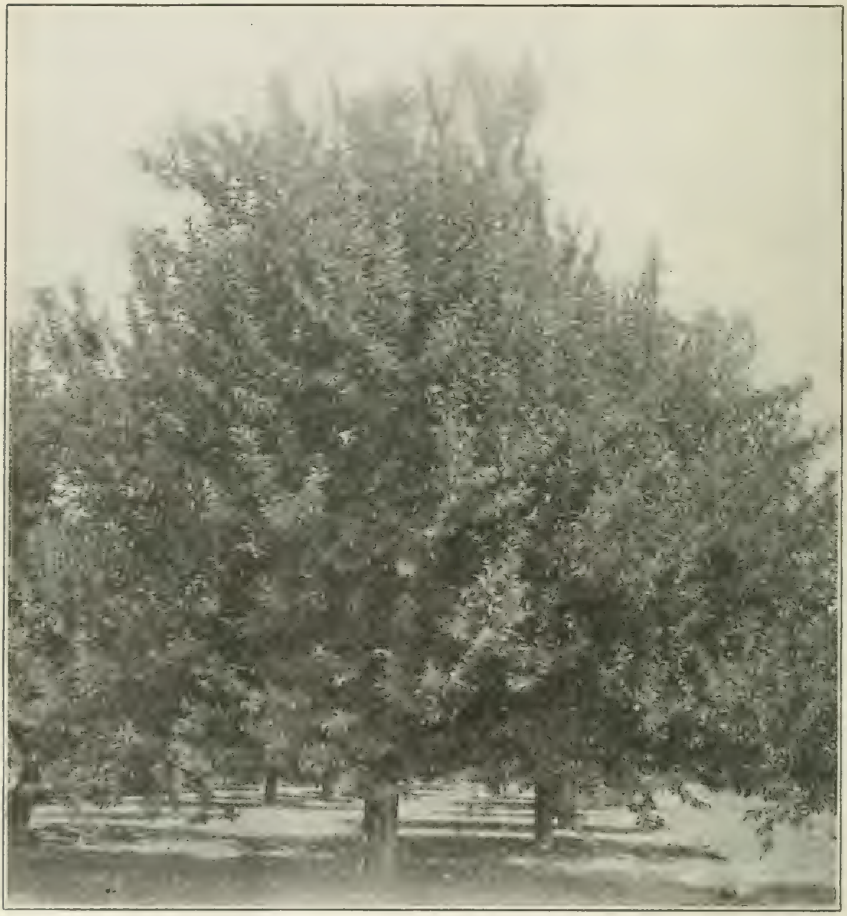

FIG. 3.—An Early Strawberry apple tree in Delaware, about 50 years old.

Early Strawberry.

This variety is supposed to have originated in New York. It was referred to in pomological literature prior to 1840, and is widely disseminated though not extensively grown. It is quite widely distributed in the New Jersey and Chesapeake peninsula sections, but is seldom seen in other portions of this region.

The tree is a strong upright grower and apparently long lived. (See fig. 3.) It is slow in coming into bearing. As a rule, only very light crops are borne before the trees are 10 or 12 years old, or even considerably older in some cases. The fruit is small to medium; roundish conic; yellowish undercolor, frequently almost entirely overspread with red, sometimes striped with darker red; texture rather firm; very good to best in dessert quality. The season of ripening begins about the middle of July in central Delaware and lasts for two or three weeks, the fruit ripening very gradually. Several pickings are therefore necessary.

Opinions differ widely in regard to the value of this sort. It is considered one of the most profitable by some; others regard it as practically worthless commercially. The late-bearing habits of the tree have already been mentioned. This is a serious objection to many growers. Unless thoroughly sprayed, the fruit usually scabs very badly. It is too small for ordinary commercial purposes, but on account of its attractive appearance and high dessert quality it is well suited to a personal market or some special trade. It is said to bring fancy prices at some of the summer resorts along the coast of New Jersey and Delaware. It is thus evident that satisfactory results can be realized only when the fruit is grown under high culture and is skillfully marketed.

English Codlin.

As the name suggests, this variety is of English origin. It is cultivated very little in this country. In this region it is confined almost exclusively to the New Jersey section.

The tree is a good grower. Fruit roundish oblate; large; yellowish green, with bronzing on exposed side; subacid; quality good, especially desirable for cooking.

The place which this sort fills in the early-apple growing industry of the New Jersey section is rather distinct from that held by most other early varieties. As indicated elsewhere most of the early apples are marketed in baskets or other small packages, but this variety is generally shipped in barrels. It meets with special favor in the Boston markets, where very satisfactory prices are usually realized. It does not reach maturity in this section until the last of August or first of September, but it develops to a good size for culinary purposes, for which it is especially valued a month previous to this time, and as soon as it is large enough to cook harvesting and shipping are generally begun. While in some sections it may be held until fully matured, the above method is said to be one of the most satisfactory ways of handling it in New Jersey.

The variety is particularly well adapted to the heavier soils in this section, and when the trees are well cared for, nearly annual crops are produced. A single grower in the Virginia section of this region has reported this variety. In this case it is highly prized.

Fanny.

The Fanny apple originated in Lancaster County, Pa. It is referred to in the revision of Downing's "Fruits and Fruit Trees of America" for 1869 as "a new apple of great promise as a market sort." It is not, however, very much grown in any section. It is in a few orchards in the New Jersey and Chesapeake peninsula sections, but is relatively unimportant at present.

The tree is a fine grower in the nursery, of upright habit, and good vigor. In the orchard it is only moderately productive. In fact, some growers offer this as one objection to it. The fruit is medium or above in size; clear yellow undercolor, overspread with bright red, showing some stripes of a darker shade; pleasant subacid flavor; good to very good.

Its season in central Delaware is the last of July and early August, though it frequently extends over a considerable period. As a commercial variety for this region it is of doubtful value. In at least one orchard which is in a good state of cultivation, the fruit nearly all drops soon after it sets. Some growers speak of it as quite irregular in the degree of perfection which it attains from year to year. On the other hand, other growers state that it gives satisfactory results under their conditions, though in some of these instances it is not considered of much value commercially. It is evidently more easily influenced by conditions than many varieties.

Garrettson. Synonyms: *Garrettson's Early*, *Somerset Harvest*.

This variety originated at Somerset, N. J. It has never been much disseminated and hence is but little known in any section.

The tree is a spreading grower, and is reported to be prolific. Fruit medium to large; bright greenish yellow; mild subacid; not of high dessert quality, but good for cooking. It ripens during the last of July and early August in the central part of the Chesapeake peninsula. The variety has not been sufficiently tested to determine its value in this region. It is doubtful if it is in any way superior to other better known sorts of the same season.

Glowing Coal.

This variety was disseminated some years ago by a New Jersey nursery, but it has not become generally known in this region. By some it is considered identical with Ohio Nonpareil, but available evidence does not support this opinion. It has been observed in but a single orchard, which is located in west-central New Jersey. The trees in this case are but 10 or 12 years old, hence it is not possible at the present time to draw any very definite conclusions about the merits of the variety. They have made a strong healthy growth. Light crops have been produced thus far, though the trees have blossomed full several times.

The fruit is large; roundish; greenish yellow, washed and splashed with crimson and with a slight overspread of gray; pleasant subacid; good to very good. Its season in west-central New Jersey is the last of August to the first of September. The tree characteristics and the quality of the fruit would make this variety a desirable one for its season, but it can not be generally recommended on account of its fruit-bearing proclivities.

Golden Sweet.

This variety is of Connecticut origin. It is not much grown in any section, but widely disseminated. In this region it is in a few orchards at widely separated points.

The tree is a strong grower and a good bearer. The fruit is large; roundish; yellow; rich, sweet; good to very good. It is considered by those who have it in this region a desirable variety for a sweet summer apple. As there is but small demand for sweet apples, however, it is doubtful if this would be a profitable market sort here. Its season is the last of July to the first of August in the middle sections of this region.

Grand Sultan.

This variety is of Russian origin; it is but little grown in this country. In this region it is in but a very few orchards. The one in which it has been under close observation for several years is located in the central part of the Chesapeake peninsula. The chief point of interest concerning it is its similarity both in tree and fruit to the Yellow Transparent apple. Its resemblance to Thaler is also close enough to be a source of considerable confusion. The best distinguishing difference between the Grand Sultan and these other two varieties, as grown in the section mentioned, is its relatively short, thick stem, which is a fairly constant characteristic.

There are perhaps more marked differences between this variety and the Yellow Transparent in some other regions. It is claimed in one section, at least, that the Grand Sultan tree is more vigorous and more upright in habit of growth than the Yellow Transparent and that it is more subject to twig-blight and less productive. These differences, however, as already noted, do not appear under the conditions existing where these varieties have been critically observed for a number of years. The Grand Sultan apple bears early and abundantly. Its season is the same as that of the Yellow Transparent.

Gravenstein.

This is a German introduction, but when it was first brought to this country is a matter of doubt. It appears quite certain that two trees were imported and planted in a garden in Boston in the spring of 1826. There is some evidence that scions were imported at another time; this may or may not have been at an earlier date. The variety is widely distributed throughout the country. In this region it is one of the most common and important varieties of its season, except in the North Carolina section, where it is rarely found.

The tree is a strong, vigorous, spreading grower, producing a large bearing surface. It comes into bearing fairly young, but not so early as some others. Under high culture it produces nearly annual crops, but as ordinarily grown the "off-year" crop is usually small. It is, however, a heavy bearer in full crop years. The fruit is medium to large; roundish oblate, angular; yellow, striped and splashed with bright red; subacid, aromatic; very good.

It is primarily an August apple in New Jersey and the Chesapeake peninsula, though the "drops" are frequently shipped the last of July. Most of the fruit is usually shipped from points as far south as central Delaware by the middle or 20th of August, while it is frequently held in some of the New Jersey orchards until some days into September.

The characteristics of the fruit make it an excellent general-purpose variety. It is excellent for cooking, for dessert, and likewise a good shipping variety. Its long season of ripening commends it for the home orchard where only a few trees can be grown. It is said to be a satisfactory variety to put in cold storage. While there has been very limited experience in handling it in this way, as is true of all early varieties, the possibility of holding it when desirable to do so may be worthy of consideration by growers in this region.

Hawthornden.

This is a Scotch variety which was brought to this country many years ago and which has been disseminated to a slight extent in some sections. So far as observed it is confined in this region to a very small number of orchards in the New Jersey and Chesapeake peninsula sections. It is unknown to most growers.

The tree is said to be a slow grower in these sections and is improved by top-working on some other vigorous sort. It bears annually and abundantly. The fruit resembles that of Maiden Blush somewhat; there appears to have been some confusion between these two varieties. Fruit medium to large; roundish oblate; pale yellow, with blush on exposed side. It ripens early in August, the same season as Maiden Blush, and is considered superior to that variety by the small number of growers who have expressed an estimate of its value. The general reputation of the variety, however, places it as inferior to Maiden Blush in flavor.

Horse.

Much confusion exists in regard to the application of the name Horse, as several sorts of doubtful identity are known more or less locally by it. In some sections the name has nearly the significance of a type name, any large, yellow apple ripening early in the season being called a Horse apple. The variety to which the name is properly applied has been in cultivation many years. Its place of origin is obscure, but it is commonly credited to North Carolina. It is found in many of the older orchards throughout the South. At one time it was considerably planted in Indiana, but it is rarely found in the North. In this region it is common in the North Carolina section, occasionally in Virginia, but rarely elsewhere.

As observed in the North Carolina section, the tree is considerably subject to twig-blight; trunk or stem tumors are also common. However, the trees are given very little attention here, so that in comparison with the standard varieties in other sections of this region this fact should be considered.

For the purpose of aiding to establish the correct identity of this variety a detailed description of it follows: Form roundish; size large; cavity regular, medium size, deep, abrupt with some russet markings extending over base; stem short, medium stout; basin regular, medium size, slope gradual, furrowed and russeted; eye very large, open; surface moderately smooth except ribbing; color yellow, with delicate blush on some specimens, sometimes small patches of russet; dots variable, mostly small; flesh yellow, medium-fine texture, juicy; core round, conic, clasping, medium size, partially open; flavor subacid, rather rich; quality good to very good. Its ripening season extends over a considerable period, beginning in the North Carolina section by the middle of July and continuing through August.

Under good conditions this would doubtless be a satisfactory sort for southern latitudes of low elevation, both for home use and local markets.

Jefferis.

This is a native variety of Pennsylvania, having originated with Mr. Isaac Jefferis, Newlin Township, Chester County. It was awarded a premium offered by the Pennsylvania Horticultural Society for the best seedling exhibited in 1848. It is quite widely distributed through the North, but is to be found mostly in the older orchards. It is almost unknown in this region, having been observed in only two or three orchards which are widely separated from one another.

The fruit is medium in size, oblate; greenish yellow with broken stripes of crimson; sprightly subacid; quality, very good. It has a comparatively long season, which in the Virginia section of this region begins about July 20. Its high dessert quality commends it for home use and a fancy retail trade, but it is too small for general commercial purposes. It would apparently do well in the central and northern sections of this region under good cultural conditions.

Jersey Sweet.

The origin of this variety is doubtful, but New Jersey is commonly supposed to be the section whence it came. It is quite widely distributed in the North, though it is not extensively grown. It exists in a few orchards in the central sections of this region, but is unknown to most of the growers.

The fruit is medium to large, roundish; yellow undercolor washed with mixed light red, splashed and striped with bright crimson; sweet, rich; of very good dessert quality. In the Virginia section it usually begins to ripen from the 10th to the middle of August. It may be worthy of consideration as a sweet variety for this region and is referred to here primarily to call attention to its possible value.

July. Synonym: *Fourth of July.*

This variety, which is of the Tetofski type, is said to have reached this country from Cassel, Germany, and to have been introduced by Mr. C. F. Jaeger, Columbus, Ohio. On the other hand, another account states that it was introduced into England from Russia during the lifetime of Mr. Thomas Andrew Knight, and thence found its way into Virginia. From this section it was disseminated northward and westward under the name Fourth of July, its original name having been lost. Though apparently more or less distributed in various sections of the country, it remains unknown to most fruit growers. In this region it is confined primarily to the Chesapeake peninsula section.

The tree makes a vigorous upright growth, with large, glossy, rather coarse foliage. (See fig. 4.) It begins to bear young, trees 3 and 4 years old frequently producing some fruit, but it does not reach full bearing as young as some varieties do, neither has it proved as uniformly productive. Some orchards which have been planted 10 to 12 years have not yet borne much fruit, though light crops have been produced for several years. The general conditions, however, in the particular orchards in question are not materially different, so far as can be determined, from those of other orchards in which more satisfactory results have been obtained. The fruit is above medium in size; conic; dull yellowish, lightly washed and striped with red; subacid; good.

In the commercial orchards of the Chesapeake peninsula this variety ranks as one of the important market sorts, yet it is not held in universal favor, even in different orchards which are under practically uniform conditions. Perhaps its strongest claim to an important place is its early season of ripening. In many orchards in this section it is often nearly all marketed by July 10, though in such cases it is usually picked in a rather immature condition. From the middle to the 25th of July, as a rule, may be considered its normal season. It appears to be rather more susceptible to the influence of relatively slight cultural differences than many varieties are.

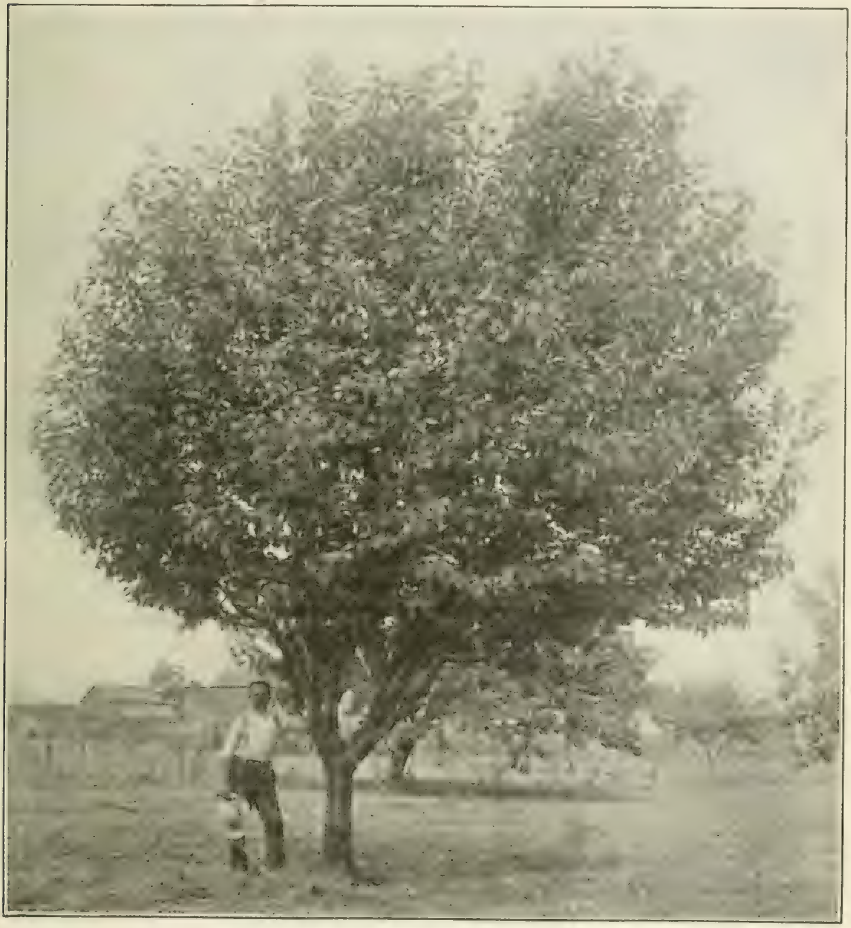

FIG. 4.—A July apple tree in Delaware, 12 years old.

If the fruit is bruised it quickly turns dark; it also discolors badly if slightly overripe, and sometimes cracks. While fairly heavy crops are frequently produced, there is usually a larger percentage of culls than in many varieties. The fruit is borne largely in clusters, especially if the trees are heavily loaded. It will thus be seen that this variety possesses rather serious faults, yet it is considered a fairly profitable variety by many on account of its sequence in ripening and the time at which it can be marketed.

Kane. Synonyms: *Cain, Cane, Red Cain.*

This variety originated in Kent County, Del. It has been disseminated but very little; even in the section where it originated very few growers have any knowledge of it.

The tree makes a good growth and apparently bears fairly well. The fruit is medium to above in size; oblate conical, regular; whitish yellow with waxy appearance, heavily shaded with crimson; crisp, juicy; good. In the Chesapeake peninsula section its season is about the middle of September or before, but the fruit will keep several weeks. While not strictly a summer sort, it apparently has some merit for its season, though not sufficiently tested to determine its full value.

Keswick. Synonyms: *Codlin, Keswick Codlin.*

This is an English variety which has been grown more or less in this country for many years, but not extensively in any section. It is in a few orchards in the New Jersey section of this region.

The tree is moderately vigorous. The fruit is medium to large; roundish oblong, conic; greenish yellow; acid; good. Its season of ripening is about the same as that of the English Codlin, but as in case of that variety it is frequently shipped before it is fully mature. On some of the heavier soils of this region, which are to be found in the section from which this report comes, the fruit is said to have a soft texture, does not mature well, and is of little commercial value. It is reported to have been substituted frequently by nurserymen in filling orders for the English Codlin, to which it is claimed to be very much inferior in the section above named.

Kirkbridge. Synonym: *Kirkbridge White.*

The place of origin of this variety is unknown. Many years ago it was planted considerably in the Middle West, especially in Indiana, being brought there from New Jersey by Quakers when going to that State for their yearly meeting. At the present time it is almost unknown in this region, being reported from only one or two points.

The tree is a slow upright grower and an early abundant bearer. The fruit is roundish; medium size; color, greenish white, sometimes with slight bronzing on exposed side; tender, juicy, subacid; good. In Delaware it ripens about the middle of July.

Lowell. Synonyms: *Greasy Pippin, Tallow Apple.*

This variety is of unknown origin, aside from the fact that it is a native sort. It is quite widely distributed in numerous sections of the country, especially in the older orchards. It is rarely found in this region, but occurs occasionally in orchards in the northern sections.

The tree is a vigorous, spreading grower, and produces nearly annual crops. The fruit is above medium size, yellow, brisk acid flavor, and good to very good in quality. In the New Jersey section it begins to ripen about August 1. It is rather perishable, decaying soon after mature, or in some cases even before; its period of ripening extends over a space of 2 or 3 weeks. The premature decay of the fruit renders it less desirable than some other sorts of the same season.

Maiden Blush.

The Maiden Blush apple originated in New Jersey many years ago. It was first described in 1817 by Coxe, who then stated that it was esteemed in the Philadelphia markets. It is grown and still being planted over a wide range of territory and is remarkable in the fact that it is successful in so large a number of the apple-growing districts of the country. In this region it has been widely planted, though relatively of much greater commercial importance in the New Jersey section than elsewhere. It is, however, a standard sort for its season in the Chesapeake peninsula section. At southern points in the region it is found much less frequently, but is a variety known to many who have orchards.

The tree is a strong grower, as a rule, seldom showing defects of any kind. (Pl. IV, fig. 1.) With good culture, nearly annual crops are produced. The fruit is above medium size; pale yellow with blush, sometimes becoming a brilliant red on exposed side.

In some locations in Delaware shipments usually begin the last of July, but in New Jersey, where it has become of most importance, its shipping period is usually from the middle to the last of August. It is a valuable market sort, though it does not ripen at the season of highest prices. It is considered one of the standard sorts for the sections in this region where it is most grown.

A few growers who have this variety report adversely concerning it, but such experiences are rare. No explanation for such results is apparent. It may require higher cultural conditions than some varieties.

A few growers have put the fruit in cold storage for a period of two to four weeks with gratifying results. It is said to hold well in storage for the time named, and this permits placing it on the market in some seasons, at least, when prices are better than they frequently are during August.

Metz.

This variety is said to have originated in Jones County, N. C. It has apparently been distributed to a small extent locally, but is not widely known, even to those who have orchards in the tide-water section of this State.

The tree makes a fine, healthy growth, noticeably free from fungous diseases. The fruit is good size, oblate, smooth, more or less striped with red. It ripens in North Carolina the last of July and early in August. It is said to be excellent for cooking, and especially good for cider, producing a much larger quantity of juice than most varieties. It is recommended by some for growing near the coast.

No mature specimens of this variety have been seen by the writer. Its merits, aside from the tree characteristics noted above, are given here as reported by parties who are growing it.

Muster.

Aside from the fact that this variety was introduced many years ago, having been described by Warder in "American Pomology," published in 1867, nothing appears to be known relative to the history of this sort. It is likewise almost unknown to fruit growers. As far as observed, it is confined to a single orchard in this region, which is located in Caroline County, Md.

The tree makes a good growth with noticeably healthy foliage. The fruit is medium or above in size; oblate; yellow, covered with mixed red and crimson; fine grained, juicy; subacid, aromatic, rich; best quality. Its season is from the middle to the last of August in the section above mentioned. It is considered a valuable variety by the one grower who is acquainted with its merits, with whom it is proving nearly an annual bearer. Its high dessert quality commends it for home use, though for commercial purposes its season of ripening may be such that it would not be regularly profitable.

Oldenburg. Synonyms: *Duchess of Oldenburg, Dutchess, Borovitsky.*

This variety is of Russian origin. It is commonly supposed to have been first introduced into this country in 1834 by the Massachusetts Horticultural Society[a] at the same time that Alexander, Red Astrachan, and Tetofski were imported from the Royal Horticultural Society, London, England. However, unless the synonym Borovitsky was applied at a very early date to some other variety, it was introduced prior to 1833.[b]

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[a] See the quotation under Alexander for further historical information.

[b] Genesee Farmer, vol. 3, no. 24, 1833, p. 188.

The Oldenburg apple has become widely disseminated in many States, especially in the upper Mississippi Valley, where it is of value on account of the hardiness of the tree. It is not extensively grown in the Middle Atlantic States, though it is well represented in the sections where commercial orcharding has been developed. Occasional trees of it are also found in the more southern sections of this region.

The tree is a good grower, fairly vigorous, with dark, healthy foliage, though evidently not making a large tree. Some twig-blight has been observed, but it is not common. The tree forms a roundish, though spreading head. It bears nearly annually, usually producing abundant crops. The fruit is medium in size or above; yellow undercolor, well streaked with red when ripe; subacid; good. Its market period varies somewhat from year to year and with different growers. About the middle to the last of July, however, appears to be an average date for marketing in the New Jersey and Chesapeake peninsula section, but the fruit can be cooked satisfactorily before it is mature. It ripens quite evenly; the entire crop can frequently be gathered in two pickings. It keeps well after it is picked, having a tendency to shrivel instead of decaying, especially if picked before fully ripe. Its use is for culinary purposes rather than for dessert.

This is proving one of the most satisfactory varieties among the earlier sorts for growing near the coast at southern points. It would apparently be a profitable sort to grow more extensively in this region than is being done at present.

In this connection attention should be directed to the fact that there are several Russian varieties of the Oldenburg type which are very similar to that variety both in appearance and in season of ripening. Due care should be taken not to confuse any of these sorts with Oldenburg.

Orange Pippin (New Jersey).

This is a very old variety of unknown origin. The earliest records trace it to Genesee, N. Y., though it is not assumed that this was the place where it originated. It is commonly supposed to have come in the first place from New Jersey, where it is now cultivated to a limited extent in some of the older orchards. It evidently is rarely found elsewhere in any of the other fruit-growing sections of the country.

The tree is thrifty and long lived. The fruit is medium to large; yellow; subacid; and good to very good. It reaches maturity from the first to the middle of August, though as with so many of the early sorts it is frequently shipped at an earlier period, before it is fully ripe. It is said to hold well in cold storage for a short period, but it has not often been handled in this way.

There is a French variety by this name, but it is a later apple.

Parry White. Synonym: *White Wax.*

The origin of this variety is uncertain, but it probably came either from Pennsylvania or New Jersey.

So far as observed, it is grown commercially only in the New Jersey section of this region, and even here it is not an important sort. While the trees tend to bear annual crops under the best care and very heavy crops on alternate years under ordinary culture, the fruit is too small to be profitable, especially as it possesses no characteristics which make it particularly desirable in any way. It is a small, rather sprightly subacid apple with a white skin, beginning to ripen the latter part of July in New Jersey, but extending over a relatively long season.

Porter.

Porter is a New England apple which originated on the grounds of Rev. Samuel Porter, Sherborn, Mass., about 1798. It is found in many sections of the North in the older orchards. In this region it is quite common in the New Jersey section, but practically unknown to growers in other sections. The tree is long lived and not possessed of any serious faults.

The fruit is medium to large; oblong conic; yellow, in some cases having considerable blush on the side exposed to the sun; very good to best quality. Its season is about August 1 to 15.

It bears fairly well in New Jersey, though not as regularly as many other sorts. The fruit does not "take" well on the market, even though of good size and attractive appearance. It is therefore not a profitable apple to grow. It is a variety primarily for home use, either for dessert or culinary purposes.

Primate.

Until quite recently the origin of this variety was obscure, but investigations made within the past few years have apparently been successful in tracing it to its original source. In this connection the following quotation is of interest:

"The first tablet in New York State in memory of any apple was erected in the town of Camillus, Onondaga County, on the original site of the Primate apple tree. John T. Roberts, Syracuse, N. Y., on the 11th of September, 1903, caused a bronze tablet to be erected there. On this tablet is the following inscription:

On this farm Calvin D. Bingham, about 1840, produced the marvelous
PRIMATE APPLE.
Named by Charles P. Cowles,
God's earth is full of love to man.

"The ceremony called together a goodly number of people. It was a beautiful thing thus to commemorate an apple that is famous throughout New York State."[a]

This variety is quite common through the North and East, though not grown extensively. So far as observed, it is confined to the New Jersey section of this region. It is, however, in only a small number of orchards. Here the tree is not a strong grower, being considered somewhat tender and rather short lived. It is only moderately productive.

The fruit is medium in size or above; greenish white with slight blush on exposed side; subacid; and good to very good in dessert quality. Its season is about the middle of July, but it frequently extends considerably later as the fruit does not mature uniformly. The fruit is tender fleshed, hence not considered a good sort for shipping to distant markets, though good prices are reported when it is well handled. Its high dessert quality recommends it, however, for home use.

Randolph. Synonym: *Unknown.*

Though the exact origin of this variety is not known, a single tree, or at most, two trees of it, standing on a farm in Newcastle County, Del., were the first to receive recognition. This occurred in 1869. What was the source of this tree or trees, if there were more than one, has never been determined.[b]

The variety has been distributed in a limited way in the middle latitudes in the East and Middle West, but is not grown extensively. In this region, so far as observed, it is confined to orchards in Kent County, Del. But here it is not considered an important variety at the present time.

The tree is a vigorous grower, but in most orchards where it has been observed it is inclined to be less prolific than is desirable, and the foliage is often injured by some of the leaf-blight fungi. The fruit is small to medium in size; white, washed with crimson and striped with darker crimson; firm texture; mild subacid flavor, but not of high quality. Its season begins about the middle of July, continuing for about two weeks.

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[a] Proceedings of the Fifty-third Annual Meeting of the Western New York Horticultural Society, 1908, p. 151.

[b] For further historical information and detailed description of this fruit, see Yearbook for 1902, U. S. Dept. of Agriculture, p. 472.

While the Randolph apple possesses some good qualities, particularly firmness of texture and attractiveness of appearance, and ripens at a fairly good time, yet, on account of its small size and light, irregular bearing proclivities, it is not considered of special value by most of the growers in this section. The fact that it ripens practically with Williams, which is a finer and larger apple, has also had an influence in the matter, the latter being considered superior in essential particulars. In certain sections of the country, where it is being grown in a limited way, greater value is attached to it than by the growers in Delaware.

Red Astrachan.

Though this variety is of Russian origin, doubtless from the province of Astrachan, it evidently first reached this country through England, being introduced by the Massachusetts Horticultural Society in 1834.[a] It was also introduced direct from Russia in the large collection of varieties imported in 1871 by this Department.

This variety is generally distributed throughout the North, and is also one of the most important early varieties in this region. It is grown more at southern points in the region than most other early varieties. It is reported as doing fairly well in close proximity to the salt water at points along the Virginia coast, as well as at other places farther south.

The fruit is medium to large; under color greenish yellow, almost entirely covered with deep crimson, in some cases showing more or less striping; flavor a sprightly acid, too sour to be pleasant for dessert purposes, but excellent for cooking. In season it is essentially a July apple in the central and northern sections of this region. The characteristics of the tree are shown in Plate IV, figure 2. It is a strong grower, with heavy dark foliage. It is late in coming into bearing, seldom producing much fruit before it is 8 to 10 years old. Heavy crops are generally borne every other year, with light ones on the "off" year.

In the New Jersey section but few are marketed before the 10th to the 15th of July. In the North Carolina section its season begins by the middle of June. As the fruit matures unevenly, the ripening period extends over a space of two or three weeks. It should be picked as soon as the fruit is fully ripe, or slightly before, else it soon becomes mealy and often cracks.

The fruit is borne largely in clusters, the individual specimens of which ripen irregularly, one at a time. It is difficult to gather the ripe apples without at the same time removing large quantities of fruit which have not reached a desirable stage of maturity. When the fruit is shipped as soon as it reaches a desirable size, as is frequently done, without special regard to color, the proportion of poorly colored specimens in a picking is of little or no consequence; but when highly colored fruit is desired, this characteristic is objectionable in the variety.

The fruit is somewhat inclined to decay in some orchards before it is ready for market, but this is not a general experience in this region under good cultural methods. There are apt to be a good many small and otherwise unmarketable apples, so that in close grading there is a heavy percentage of low-grade fruit and culls.

While this variety has some rather serious faults in this region, it also has many points of merit, and there appears to be no other red sort to substitute for it, especially in point of season.

Red June. Synonyms: *Carolina Red June, Carolina Red, North Carolina Red June.*

The place of origin of this variety is in doubt, but it is generally assumed to be North Carolina. It has long been in cultivation and has become very widely disseminated, especially in middle latitudes and the South. In this region it is quite common in the Chesapeake peninsula and Virginia sections, and in the North Carolina section it is perhaps grown in more orchards than any other early sort.

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[a] See the quotation under Alexander for further historical information.

The tree is of fairly vigorous, upright growth and generally productive. The fruit is small to medium in size; oval, somewhat irregular, inclined to be conic; when fully colored nearly the entire surface is deep red, with a light bloom; tender, juicy, with brisk subacid flavor; quality good to very good. Its season of maturity usually begins from June 10 to 15 in the North Carolina section; in Delaware it averages about three weeks later, continuing for about two weeks.

Under good cultural conditions it bears more or less annually, with a good proportion of fairly heavy crops. It probably does not withstand neglect as well as some varieties do, but it responds readily to good culture. The foliage is somewhat subject to some of the leaf-spot fungi. Apple scab is frequently serious on the fruit if not well sprayed, but with proper attention to these details excellent fruit of the variety is grown. There are some indications that rather finer fruit is produced on the heavier soil in this region than on the very light sandy types.

The small size of the fruit is the most serious defect as a commercial variety. Some seasons, however, it is profitable as a market sort and is always desirable as a dessert apple for home use.

In some sections of this region, especially in North Carolina where this sort has been widely grown for many years, there is a considerable number of varieties, mostly unnamed and of local distribution, that very closely resemble Red June in appearance and in other ways. They may be seedlings of this variety, though as a rule little or nothing is known of their origin. The most of them ripen about with Red June and are similar to it in size, color, and flavor. Others are larger in size, some are distinctly more acid, while still others are sweet in flavor.

Roadstown. Synonym: *Roadstown Pippin.*

This is a local variety which originated in southern New Jersey near a place by the name of Roadstown, and, so far as observed, its cultivation has not extended much beyond the region of its origin.

The tree is a strong upright grower. It produces very heavy crops and tends to bear annually. The fruit is large; greenish yellow, frequently bronzed on the exposed side; subacid; rather oblate in shape; good dessert quality, and especially fine for cooking. It does not reach full maturity until about September 1, but it is a large apple and develops to a good size for culinary purposes relatively early in the season, so that shipping begins by the latter part of July. In this respect it is similar to English Codlin, and like this variety it usually meets with a ready sale in the Boston markets at more satisfactory prices than most other varieties with which it comes into competition. In this section of New Jersey, where the soil is heavier than in most places in this region, the fruit apparently possesses much merit as a commercial sort. It is suggested for careful testing in other sections.

Sandbrook.

This variety originated near Sergeantsville, N. J. It was introduced about twenty years ago, but it has not been much disseminated. It is growing in a very small number of orchards in the Chesapeake peninsula and New Jersey sections of this region.

The tree is a strong grower in the nursery, but of moderate growth as it becomes older. It is prolific when full bearing age is reached. The fruit is small to medium; prettily washed with red and striped with bright crimson; subacid; good to very good. It ripens from the last of July to the middle of August in the central part of the Chesapeake peninsula. The small size of the fruit renders it undesirable for market, but it is considered valuable for home use by some growers.

Smokehouse. Synonyms: *Gibson's Vandevere, Mill Creek Vandevere, Red Vandevere.*

This is a very old variety which apparently originated during the latter part of the eighteenth century on the farm of Mr. William Gibson near Lampeter, Lancaster County, Pa. It was called Smokehouse because the tree stood near the building used for smoking meats. It is widely known in the middle latitudes south of and including

Pennsylvania and east of the Mississippi River, though not grown in large quantities. Occasionally it is grown farther west, but not commonly. In this region it is more of a fall apple than a summer variety, although at southern points it should be grouped with the early sorts. It is more often found in the New Jersey section than elsewhere, but it holds relatively an unimportant place.

The tree makes a large, spreading top; it probably does not come into bearing quite as early as many varieties do, though not considered particularly late in reaching bearing age. The fruit is medium to large; greenish yellow, washed and mottled with red or crimson, sometimes more or less overspread with gray; prominent russet dots; subacid; good to very good. In the New Jersey section, as above indicated, it is a fall apple, ripening about the middle of September, and it may be kept for several weeks or even months, but at southern points it reaches maturity the first of September.

For a large portion of this region this appears to be a good general-purpose variety for its season. The trees bear well; it is a good market variety of sufficiently high dessert quality to have a place in home orchards.

Sops-of-Wine.

This is an old European sort which has become more or less disseminated in this country, but it has never been extensively grown. It is seldom included in recently planted orchards. It is rarely grown commercially in this region, but an occasional tree of it is found in a few orchards in the central and northern sections.

The tree makes a good growth and bears at an early age. The fruit is roundish, medium size, yellow, shaded and splashed with deep red, frequently becoming so completely shaded that the striping is obscured. Flesh is rather dry, subacid, and possesses a peculiar characteristic flavor which is exceedingly pleasant to some, but less agreeable to others. The fruit ripens about the middle of July. It often decays rather badly about the calyx before it is ripe, and drops considerably. Under neglected conditions the fruit is very irregular in size; also scabs badly if not sprayed. So far as observed, and in the opinion of those who know the variety in this region, there is little to recommend it for planting here.

Starr.

The best available records indicate that this variety originated near Woodbury, Gloucester County, N. J., on the grounds of Judge John Moore White, which were later owned by a Mrs. Starr. A son of Mrs. Starr is said to have been in the legislature about 1865 with the late William Parry. He gave Mr. Parry some scions of this variety, who propagated it under this name. The Starr has remained comparatively unknown in most sections, and in this region it is confined almost entirely to the New Jersey section, where it is grown to a considerable extent.

The tree makes a strong upright growth; bears early and abundantly, giving nearly annual crops under good cultural conditions. (See fig. 5.) The apple is large; roundish oblate; greenish white; subacid; good. It matures somewhat irregularly, but it is essentially a July apple in season, usually beginning to ripen by the 10th to the 15th of the month though not fully ripe until about the first of August. A good size is reached comparatively early, and as it cooks well before it is ripe, it is generally marketed accordingly. In fact, it should not be allowed to become too ripe before picking as it soon becomes mealy. Picking may thus be governed in a measure by market conditions, and if desirable its season may be made to extend over a considerable period. It is essentially a cooking apple, for which it is much sought after by those who know its qualities for this purpose.

In a few instances the trees have twig-blighted badly, but this is not a usual experience. The fruit shows bruises rather badly, which necessitates careful handling.

This variety possesses qualities which would appear to recommend it for more general planting in a large portion of this region. It is growing in importance.

Summer Hagloe. Synonym: *Hagloe.*

This is a very old variety supposed to be of American origin, though at one time apparently confused with an English cider crab apple called "Hagloe" and attributed to an English or European origin. Details of its early history, however, are obscure. It is not known to fruit growers generally, but in this region it is of considerable importance in the New Jersey and Delaware sections, though rarely grown in any of the other sections. The tree is a slow grower; the terminals are rather thick and blunt, thus making a tree of quite distinctive appearance. (See fig. 6.) Under good conditions of culture, very heavy crops may be expected in these sections on alternate years, and usually considerable fruit in "off years." It usually bears at 5 or 6 years of age.

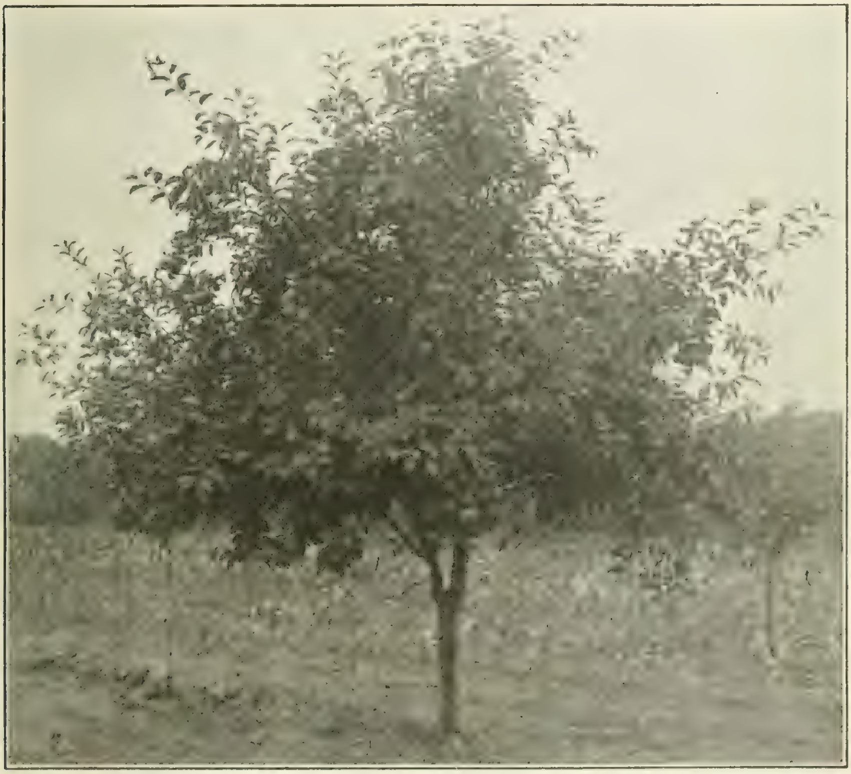

FIG. 5.—A Starr apple tree in New Jersey, 8 years old.

The fruit is medium to large; oblate; whitish yellow, lightly striped and splashed with red on the exposed side, rarely becoming more highly colored; flesh rather tender, juicy, subacid; quality good; valuable for cooking rather than for dessert purposes. In the sections above mentioned ripening begins from the 15th to the 25th of July and continues about two weeks. The fruit is not generally marketed until it is nearly mature.

In most of the commercial orchards in these sections where this variety is grown it is considered an important and a profitable sort to grow, selling well in the markets. An occasional exception to this experience occurs, however, even in orchards that have received unusual attention, the variety being unproductive and unsatisfactory in nearly every essential particular. No explanation of such failures is apparent.

The tree is noticeably susceptible to serious injury from the San Jose scale, even when most other varieties are damaged but slightly.

Summer King.

The place of origin of this variety is in doubt, but it is generally supposed to be North Carolina. It is not grown in any section extensively and is comparatively unknown. This applies also to this region, as it has been located in only two or three orchards.

The tree is upright in growth, vigorous, and fairly productive. The fruit is medium to large; yellowish green, striped with crimson and red; mild subacid; very good in dessert quality. The season of ripening is comparatively long, extending through August in the Chesapeake peninsula section or even longer in some cases. In the North Carolina section the fruit is ripe about the middle of July. It is highly recommended by some for this region, especially in the central and northern sections, for dessert and also for market. The fruit reaches a good size early, so that it could be shipped over a long season, as is Starr, Wealthy, and some others. It is not widely enough tested, however, to warrant making heavy plantings of it.

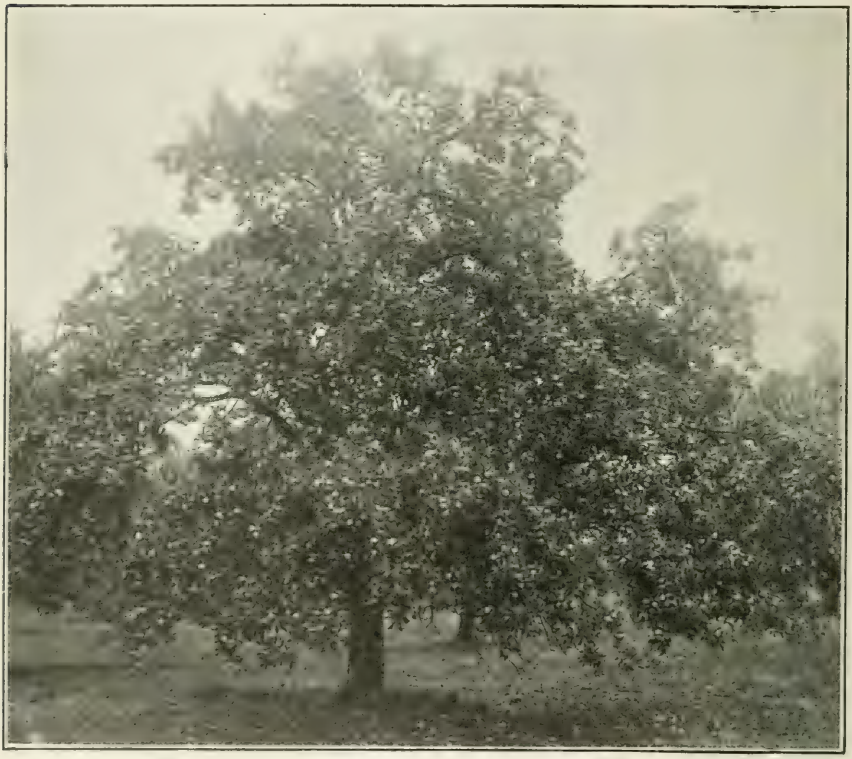

FIG. 6.—A Summer Hagloe apple tree in New Jersey, 48 years old.

Summer Rose. Synonyms: *Lippincott*, *Woolman's Harvest.*

This variety originated in New Jersey. It is an old variety, being referred to in the earliest American literature (Domestic Encyclopedia, 1804) relating to pomology. Though quite widely grown in this region it is not produced in large quantities.

The tree is a good grower, somewhat spreading, productive, bearing nearly annual crops. The fruit is small; roundish oblate; whitish, striped and blotched with red;

tender, juicy, sprightly subacid; quality is excellent as a dessert fruit. Not only the flesh, but the skin also, is so tender that bruising results from any other than the most careful handling. The small size of the fruit also further renders it of little value for commercial purposes, but its high dessert quality recommends it for home use. It is in the height of its season about the middle of July or a little later at central points in this region.

Tetofski. Synonym: *Tetofsky.*

This is another one of the Russian introductions which was brought to this country through England. Further historical details appear in a quotation under Alexander. The dissemination of this variety has been quite extensive, though it is not grown in large quantities in any section. It is in a few quite widely separated orchards in the Chesapeake peninsula and New Jersey sections of this region but it is of quite secondary importance.

The tree is a very upright fairly strong grower and a prolific bearer. The fruit is medium in size; roundish, oblate conic; juicy, sprightly acid; of good quality. It is more desirable for market and for cooking than as a dessert apple. Its season in the central part of the Chesapeake peninsula begins usually from July 10 to 15, with a rather short period of duration.

Several growers variously located in the Chesapeake peninsula and New Jersey consider this a fairly good variety for its season, though perhaps not of sufficient value to take the place of other better-known varieties of the same season of ripening.

The tree is especially hardy and is probably rather better adapted to sections farther north than it is to this region.

Thaler. Synonym: *Charlottenthaler, Government List No. 342.*

This is one of a large number of varieties introduced from Russia in 1870 by the United States Department of Agriculture. It has never become widely known, at least not under its correct name or either of its synonyms. So far as observed it is confined in this region to a single orchard which is located in Caroline County, Md.

In the present connection the chief point of interest is the similarity of the fruit to Yellow Transparent, which is one of the most important commercial varieties grown in this region. It is also very similar to Grand Sultan, previously mentioned.

Comparing this variety with the Yellow Transparent, the fruit of the two sorts is practically identical so far as any constant distinguishable characters of individual specimens are concerned. Thaler is claimed by some to be a very few days later in ripening the bulk of its crop, though this is open to question. The owner of the one orchard in Caroline County, Md., in which these two varieties, also Grand Sultan, are growing, after a considerable number of years of close observation, is convinced that as they grow in his orchard, these two—Thaler and Yellow Transparent—are not distinguishable from each other in season, productiveness, or fruit characteristics, but that there is a marked difference between the trees, Thaler being a more vigorous grower, which is readily noticeable even in the nursery, and being much less subject to twig-blight than Yellow Transparent.

In some sections of the country the Thaler tree is reported to be less vigorous and productive than the Yellow Transparent. The limited range of observation in this region does not warrant definite conclusions regarding the relative merits of these two varieties for this region, but a thorough test of Thaler in the different sections appears desirable.

Townsend.

This is a very old variety, the origin of which traces to Bucks County, Pa., where it was discovered by Mr. Stephen Townsend nearly a century and a half ago in an old Indian clearing. While grown more or less in various sections in the older orchards, it is unknown to most fruit growers. It has been observed in but a single orchard in this region, located in west-central New Jersey.

The tree is a vigorous, spreading grower, fairly productive, but the crops are mostly alternate. The fruit is medium size or above; oblate conic; pale yellow, striped with red; subacid; good to very good in quality. The fruit usually is well colored by the last of July or the first of August in this section and drops as soon as colored. The ripening period lasts for a month or six weeks. By those who know the variety the fruit is esteemed for home use on account of its high dessert quality, but it ripens too irregularly to make it a desirable market sort.

Trenton Early.

The early history of this apple is obscure; it is known, however, to have been in cultivation for a long time. It was listed by Heikes & Wharton, a Pennsylvania nursery firm, in their catalogue for 1823. It is quite widely disseminated, but, as is the case with so many varieties, it is in comparatively few orchards. It would seem probable that it is in some of the older orchards in the New Jersey section of this region, though in the course of these investigations no trees of it have been found in this section. One or two orchards in the Chesapeake peninsula section contain it, but it is not common.

The fruit is large; conical; greenish yellow, sometimes with bronzed blush; pleasant subacid; good to very good. Its season in the sections named would probably begin the last of July or early in August.

Wealthy.

The exact date of origin of this variety is uncertain, but it was about the year 1861. The fruit was first described in 1869. The original tree is stated to have been grown from a collection of crab-apple seed which Mr. Peter M. Gideon, of Excelsior, Minn., obtained from Bangor, Me. There is very little about the variety, however, either in tree or fruit to suggest that it is of crab parentage. On the other hand, it is said that some of its seedlings show crab characteristics. This would appear to give some support to the claim regarding its parentage.

It is one of the most important late fall and early winter varieties in the upper Mississippi Valley, where cold endurance of the tree is of paramount importance. In recent years it has become quite widely disseminated. It has been planted considerably in the New Jersey section, though rarely elsewhere in this region. It is becoming an important variety here to supplement the earliest ripening sorts.

The tree grows well, with rather long slender branches when young. The foliage is sometimes rather small and weak, though apparently not especially subject to fungous diseases. The fruit is medium to large; roundish oblate; yellowish white under color, heavily striped and splashed with red when well colored; flesh tender, juicy, subacid; quality very good; desirable either for cooking or dessert. In the New Jersey section it is fully ripe from the latter part of August to the first of September, but the variety usually bears heavily and the fruit develops to a sufficiently large size for culinary purposes relatively early. Hence marketing of the green fruit begins frequently the last of July or the first of August, the picking being so done as to thin the fruit on the overloaded trees. By such methods the green fruit is made a source of some revenue, and that which is allowed to remain until later is improved as a result of the thinning. In this way the fruit may be handled throughout the month of August. The variety is generally regarded by those who have it in the New Jersey section as a very desirable and profitable sort to grow.

Williams. Synonyms: *Williams Early*, *Williams Red*, *Williams Early Red*, *Williams Favorite*.

This variety has been in cultivation since about the middle or latter part of the eighteenth century. It originated at Roxbury, Mass., and was first exhibited in 1830 at a meeting of the Massachusetts Horticultural Society. It is grown considerably in the North and East and to a lesser extent in some other sections.[a]

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[a] For further historical information and a detailed description of this variety, see the Yearbook of the United States Department of Agriculture for 1908, p. 476.

Its distribution is general throughout the sections of this region in which the commercial growing of early apples has become important, particularly in Delaware and New Jersey. In the North Carolina section it is occasionally found, but is not of special importance at present.

The tree is rather a poor grower in the nursery as well as in the orchard, making a spreading, often rather irregular, top. (See fig. 7.) Probably top working on some vigorous upright grower such as the Northern Spy would be an advantage. Early and abundant crops are generally produced. The crops are more or less alternate under indifferent cultural conditions, but with good attention considerable fruit may be expected nearly every year. The fruit is above medium in size; roundish oblong, conic; when well colored, heavily striped with dark red or crimson, becoming nearly a solid color; subacid; quality good. The season in the New Jersey and Chesapeake peninsula sections usually begins about July 20, varying from this date a few days in different years, according to climatic and other conditions. The market period generally lasts about two weeks.

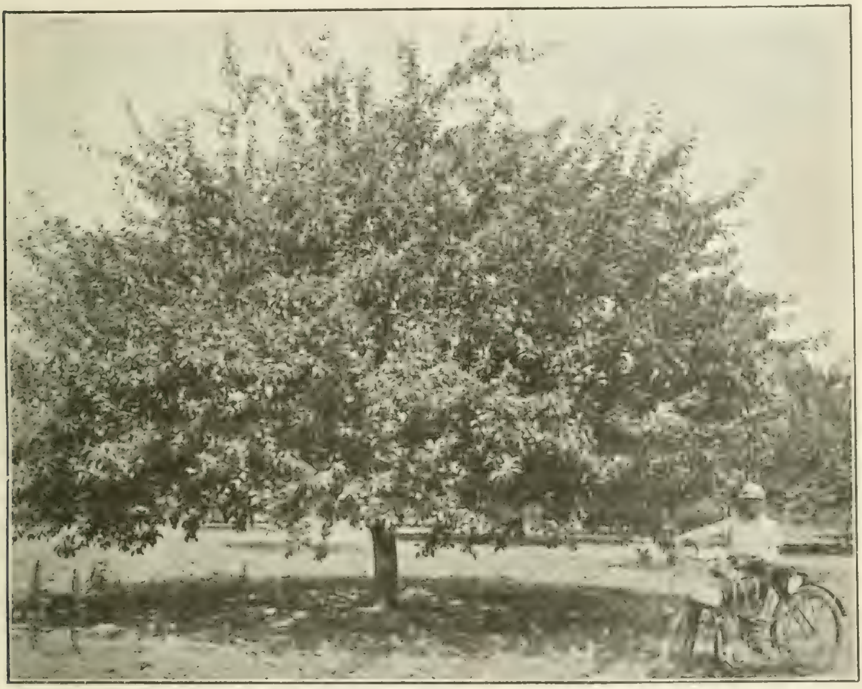

FIG. 7.—A Williams apple tree in Delaware, about 10 years old.

Some varieties, as noted elsewhere, are handled as soon as they are large enough to cook, but this one though it develops to a fairly good size is not marketed, as a general practice, until it is well colored. In fact, its fine color is one of its most attractive features. Ripening is quite irregular, so that picking is rather difficult, especially from large trees. As the fruit drops soon after attaining full color, some growers allow it to remain on the trees until it matures and drops instead of picking it by hand. (See Harvesting, p. 20.)

On account of its season of ripening, the fruit sometimes reaches the markets when they are well stocked with peaches, cantaloupes, and other fresh fruits. The prices of apples are more or less influenced thereby. Yet because of the many desirable market qualities which this variety possesses it is very satisfactory as a rule and more profitable than most of the second early sorts. It is one of the comparatively few varieties that are grown in large quantities. An occasional adverse report is heard relative to its behavior in these sections, but they are so exceptional that they do not materially affect the general standing of the variety.

There is apparently confusion in some sections of this region in connection with this variety. In the above-mentioned sections where it is commercially important it is perhaps better known by its synonyms Williams Early or Williams Early Red than by its approved name. In other sections it is commonly called by another synonym, Williams Favorite. Occasional statements are made in this region, however, that Williams Early Red and Williams Favorite are distinct varieties, the former being a scraggly, poor grower, but a good bearer; the latter, a strong, vigorous upright tree, but a shy bearer and not commonly grown.

Since the apple known to the growers of this region as Williams Early or Williams Early Red is undoubtedly Williams, as above described, considerable effort has been made to determine the identity of the variety known in this region as Williams Favorite. Though the latter variety is commonly spoken of, few growers are actually familiar with it, and it has been difficult to locate bearing trees. It appears probable, however, that the Williams Favorite of some, at least, is the Sops-of-Wine, as it has recently been determined that the latter variety has been disseminated somewhat under the name Williams Favorite, which name has been erroneously used as a synonym of that variety. Some young trees planted for Williams Favorite (of this region) and which correspond in tree characters to this variety, as above described, have been identified as Sops-of-Wine. While this still leaves the matter open to some doubt, it at least is a partial clearing up of the confusion. There may be still other varieties not yet examined in this connection which are being grown under the name Williams Favorite.

Yellow Transparent. Synonym: *Government List No. 334.*

As the synonym of this variety implies, this is one of the importations from Russia made by the United States Department of Agriculture in 1870. It has been widely disseminated, being now grown in many parts of the country. It possesses an unusually wide range of adaptability, as is evident from the high degree of success with which it is grown in many sections.

In this region it is one of the most important early varieties. It is more extensively grown in Delaware than in any other section, but it is being planted throughout the region.

Under high culture the tree makes a fairly strong upright growth for the first few years (Pl. I), but in many orchards the growth is rather short and stubby. This gives the tree a somewhat stunted appearance. Closer planting is possible than with most varieties on account of the small size of the tree. Frequently a few apples are borne the first year after the trees are planted, and often when 2 and 3 years old considerable fruit will set. Full bearing is reached at an early age. Nearly annual and fairly abundant crops may be expected in this region under good cultural conditions.

The tree sometimes twig-blights rather badly, though in some orchards it seldom appears. It is considered short lived, but because of its early-bearing proclivities and abundant crops, longevity is not so important a matter as with some other varieties. The fruit is above medium size; roundish conic; beautiful, clear yellowish white, the skin having a waxy appearance; subacid; good to very good.

In the Chesapeake peninsula section shipments frequently are made the latter part of June, often as early as the 20th to the 25th of the month. But at this time the fruit is rather immature and small. By the first week in July it is usually in prime condition for shipping from this section, and by the 10th to the 15th of July it is generally all marketed. Some growers, however, ship the fruit in a more immature condition than others, and this makes the shipping dates of one orchard differ accordingly from those of another in the same locality. In the New Jersey section the tendency is to let the fruit reach a somewhat more mature condition than is customary in the Chesapeake peninsula section, hence shipping dates are relatively later in the former section. In the Virginia and North Carolina sections the season begins from the 10th to the 20th of June. Ripening is quite uniform, so that the entire crop can usually be harvested in two pickings. If conditions are favorable for growth after the first picking is made, the fruit which is allowed to remain on the trees will develop rapidly in size so that the second picking usually comprises the best grade of fruit produced. Formerly the Yellow Transparent was considered too tender for a market variety, but experience has demonstrated that with reasonable care in handling, especially if the fruit is picked while it is still firm, fairly long-distance shipments can be safely made if the packing is well done. In some of the experimental export shipments made by the Bureau of Plant Industry this variety carried in good condition, in cold storage, to the English markets.

As mentioned under Thaler, the fruit of Yellow Transparent very closely resembles that variety, Thaler possibly being a few days later, and the tree rather more vigorous than Yellow Transparent.

PROMISING VARIETIES FOR TRIAL.

There are a number of varieties of summer apples of considerable prominence in other sections that, so far as observed, are not being grown in this region but which would doubtless be of value both commercially and for home use. Some of the more promising of these are the following:

Coffman.

This variety has been known for many years in some sections of Tennessee, particularly in Lauderdale County. It was named for the owner of the farm on which one of the first trees of it to attract attention stood. It was propagated and introduced to the trade in 1888. It is not widely known among fruit growers.[a]

It is a vigorous, upright grower and produces regular annual crops. The fruit is of the Red June type and it may be a seedling of that variety; medium or above in size; roundish; under color yellow, washed with mixed red and stripes of purplish red, turning to almost a black-red when highly colored; subacid; good to very good. It is said to ripen about with Red June.

On account of the value of the Red June apple and others of its type in some sections of this region, and the similarity of Coffman to that variety, it is considered worthy of extended trial here.

Early Cooper. Synonym: *Cooper's Early White.*

There is much uncertainty in regard to the place of origin of this variety. By some it is thought to have come from Iowa, but the evidence is not conclusive. It is grown to a considerable extent in some parts of the Middle West. In some sections of Kansas and Oklahoma it is very successful.

The tree is an exceptionally fine stocky grower, bears early, and is productive. The fruit is medium size; round or roundish oblate; clear greenish yellow; quality good. It is considered especially desirable for cooking, while its firm texture makes it a satisfactory sort for shipping. Probably it could be marketed from the central sections of this region by the last of July.

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[a] For further historical information and a detailed description of this variety, see the Yearbook of the United States Department of Agriculture for 1909, p. 377.

Summer Extra.

This variety probably originated as a chance seedling near Quincy, Ky. It is not known generally to fruit growers.

The tree is a strong, handsome grower, bears early, and is prolific in sections where it is in cultivation. The fruit is medium to large in size; roundish; yellow with blush on exposed side; pleasant subacid; dessert quality good to very good. For cooking it is said to be especially fine. It would probably ripen at central points in this region during the last of July or early August.

Summer Rambo.

The origin of this variety is uncertain, though it is commonly supposed to have come from southeastern Pennsylvania, but no definite information appears to be obtainable.

Several other varieties, notably Summer Rambour, or Rambour d'Ete, an old French variety that was formerly grown more or less in this country, Grosh, and Western Beauty have been confused with this one. But it is pretty definitely determined that these are all distinct varieties, though possessing some rather strong points of similarity.

Though not found growing in this region in the present connection, the Summer Rambo is often sold in local markets from orchards in the Maryland and Virginia sections of the adjacent region.

The tree is a strong vigorous grower and an early and abundant bearer. The fruit is described in considerable detail as follows: Form oblate; size large; cavity wide, large, deep, slope gradual; basin regular, medium, slope gradual; surface moderately smooth, some erupted russet dots; color yellow, lightly washed with pale mixed red, a few bright-crimson splashes and broken stripes; dots numerous, russet, many erupted; skin thick, tenacious; flesh yellowish, texture fine grained, breaking, juicy; core oblate, clasping, medium to small in size; flavor subacid, rich; quality good to very good. In the vicinity of Washington, D. C., the fruit is ripe soon after the middle of August. It is apparently worthy of attention in the Coastal Plain region both for commercial purposes and for home use.

Wilson June.

The Wilson June variety, as nearly as its history can be traced, came from a nursery in Washington County, Ark., that was abandoned during a portion of the civil war period. The trees were subsequently dug and planted in local orchards. The original tree was probably one that was obtained from this source.

The fruit is distinctly of the Red June type, though considerably larger than that variety and sweet in flavor. The tree is thrifty and apparently a good bearer. For many years it has been grown locally to a very limited extent, but during the past few years it has been attracting some attention and has been propagated more extensively than formerly.

Though the range of its adaptability has not been determined, it is likely that whereever the Red June can be grown successfully this variety may prove to be of value when a sweet apple is desired.

OTHER VARIETIES.

In the course of these investigations a considerable number of other varieties than those mentioned have come under observation or have been reported by growers in the interviews had with them by the writer. For various reasons it is not practicable to discuss each of these separately. In some cases the varieties are practically unknown in the region and apparently are not well adapted to the conditions or possess such characteristics as to render them of no apparent value to the fruit interests of this region. In still other cases the varieties are local and relatively unimportant. For these and other similar reasons it has seemed best to confine the discussion largely to varieties which are of value and to certain other varieties that apparently possess little or no merit but which sooner or later are likely to come to the attention of fruit growers in this region for consideration. A few other sorts not now in cultivation in this region so far as known but which are considered promising are also discussed.

In this connection there are one or two varieties, or possibly more, grown largely in a local way in the North Carolina section of this region which should be mentioned here. These are variously known as "Early May," "White May," "June Apple," etc., and ripen the last part of May or early in June.

It is possible that some of these very early sorts may prove to be White Juneating, an old English variety that was more or less grown in the South in the early years under various names.

SUMMARY OF VARIETIES.

As a means of indicating the relative importance of the different varieties referred to in the foregoing pages in the different sections of this region and the approximate time when the season of use begins, the following table has been prepared. In the column which follows the varietal names the use to which each sort is adapted is indicated by the initial letters *d*, *k*, and *m*, either singly or in combination, as is required. Varieties of special value for eating in a fresh state are designated by *d* for "dessert;" *k* signifies "kitchen" or culinary use; *m*, that the variety is suited for market purposes.

In the columns headed "Relative importance" the comparative extent to which the several varieties are grown in the different sections is shown. The varieties rated 1 are those which are grown the most extensively in the sections so designated; varieties marked 2 are grown to some extent in the sections so marked, but not so extensively as those rated as 1; varieties which are found only occasionally, hence relatively unimportant at present, are rated as 3.

Promising varieties which are at present grown but little and the value of which is not yet fully determined are grouped together and follow Table III. It should be further stated that where a variety is rated the same in a section in which early-apple culture is an important industry and one in which it is still undeveloped commercially it does not mean that that variety is of equal importance in the two sections on the basis of the quantity of fruit produced, but rather that in comparison with other varieties grown in the respective sections the relative proportions are approximately the same.

The dates given in the columns headed "Season begins about" refer to the approximate periods when the different sorts are fit for use or can be marketed, and not necessarily to the date of full maturity. Where the 15th of a month is stated, it should be broadly interpreted to mean the middle of the month; likewise the 25th refers to the last of a month rather than to an exact date. A similar interpretation should be given to other dates mentioned.

TABLE III.—*Use, relative importance, and season of edible maturity of summer-apple varieties suited to growing in the Middle Atlantic States.*

Variety.	Use.	New Jersey section.		Chesapeake peninsula section.		Virginia section.		North Carolina section.	
		Relative importance.	Season begins about—	Relative importance.	Season begins about—	Relative importance.	Season begins about—	Relative importance.	Season begins about—
Alexander	km	3	July 25						
Bachelor Blush	km	3	Aug. 25						
Benoni	d	3	Aug. 20			3	July 10		
Bonum	d					3	Sept. 1	1	Aug. 25
Bough	d	2	July 10	2	July 10				
Celestia	dkm			3	Sept. 5	3	Sept. 1		
Champlain	km	2	July 25	2	July 25				
Colton	km			2	July 10				
Cornell	d	3	Aug. 15						
Early Edward	d	3	July 25	3	July 25				
Early Harvest	dk	2	July 5	2	July 5	1	June 25	1	June 15
Early Joe	d	3	July 25	3	July 25				
Early Ripe	km			1	July 1			3	June 15
Early Strawberry	d	2	July 15	2	July 15				
English Codlin	km	2	July 25						
Fanny	k	3	...do....	3	July 25				
Golden Sweet	dk			3	...do....			3	July 15
Gravenstein	dkm	1	Aug. 5	1	Aug. 5	1	July 25		
Horse	k							1	July 15
Jefferis	d			3	Aug. 1	3	July 25		
Jersey Sweet	d			3	Aug. 15	3	Aug. 10		
July	km			1	July 10				
Keswick	km	3	July 25						
Lowell	dk	3	Aug. 1						
Maiden Blush	km	1	Aug. 15	1	Aug. 10	1	Aug. 1		
Metz	k							2	July 25
Oldenburg	km	2	July 20	2	July 20	3	July 15		
Orange Pippin	km	3	July 25						
Primate	d	3	July 15						
Randolph	km			2	July 20				
Red Astrachan	km	1	July 10	1	July 5	1	July 1	1	June 25
Red June	dm			2	July 10	1	...do....	1	June 15
Roadstown	km	2	Aug. 1						
Smokehouse	dkm	3	Sept. 10			1	Sept. 1		
Starr	km	1	July 15						
Summer Hagloe	km	1	July 20	1	July 20				
Summer Rose	d	3	July 15	2	July 10				
Tetofski	km	3	...do....	3	July 15				
Wealthy	dkm	2	Aug. 1						
Williams	dkm	1	July 20	1	July 20			3	July 1
Yellow Transparent	dkm	1	July 5	1	July 1	1	June 20	1	June 10

In Table III several varieties are rated as of first importance in either the New Jersey or the Chesapeake peninsula section, but are not mentioned as being grown at all in either of the other sections. The conditions in each section are sufficiently similar to suggest the probability that a variety which can be grown with a high degree of success in any one of them is at least a promising sort for trial in all of the others. The varieties referred to in this connection can be readily determined by reference to the above table.

Several sorts rated as 2 or 3 in the sections in which they are grown appear to possess sufficient merit for their season of ripening to warrant a more general planting of them. The more important of these varieties are Bachelor Blush, Celestia, English Codlin, Oldenburg, Primate, Roadstown, Smokehouse, and Wealthy.

In the discussion of varieties a number of sorts are mentioned which appear to be promising, but which are not sufficiently well known in these sections for them to have any particular rating in comparison with other varieties. A number of varieties are also included in the varietal discussion which are not in cultivation in any section of this region so far as is known, but which are sufficiently promising in other sections to suggest the probability of their being successfully grown in this region. These two groups of varieties comprise the following: Coffman, Cross, Dawes, Early Cooper, Glowing Coal, Hawthornden, Kane, Muster, Sandbrook, Summer Extra, Summer King, Thaler, Townsend, and Trenton Early.

PHENOLOGICAL RECORDS.

CHARACTER OF DATA.

Exact dates of the blossoming of varieties, the opening of the leaves, the ripening periods of the fruit, and its keeping qualities in different sections furnish valuable means for studying the adaptability of varieties when such data are accompanied by sufficient information concerning the age and condition of the trees or plants in question and the conditions under which they are grown. The latter should include climatological data.

Information regarding environment is essential to a correct interpretation of the varietal data just mentioned and also in order to make the data from one section fully comparable with those from another. The correlation of climatic and varietal data constitutes one feature of the science of phenology (a contraction of the word phenomenology). This science treats of the relationships of local climatic conditions and the periodical recurrence of the phenomena of plant life or, in a broader sense, of all living things, both plants and animals.

The phenological data presented in Table IV, relating to apples in New Jersey, Maryland, Delaware, Virginia, and North Carolina, recorded under the direction of the Bureau of Plant Industry by a large number of fruit growers located in different sections of these States, are appended for the purpose not only of disseminating the specific varietal information which has thus been recorded, but also because such data make possible comparisons with other sections from which important deductions may be made.

That these comparisons and deductions may be as complete and far-reaching as possible, the important varieties of apples of all seasons grown in these States are included, as well as the early-ripening ones to which the subject-matter of the foregoing pages relates. For a similar reason, the range of observations includes the entire States, of which the region under discussion in the earlier pages forms a part.

The climatological tables on pages 13 to 15, for the years 1902 to 1907, inclusive, which correspond to the years covered by the phenological data below, should be carefully consulted in studying these data, since the latter are governed largely by the prevailing climatic conditions.

A list of the names and addresses of those who have contributed the data presented in Table IV is given below. Each observer is assigned a number. These appear in the first column in the list in numerical order. For convenience in indicating the approximate geographical location where the different records were made, the number representing the observer who made each one is placed before it in Table IV in the column headed "Observer's No."

The sequence of arrangement in Table IV is by States, from south to north; under each State, it is alphabetically by counties, as are also the names of the post-offices and observers in each county. The order of the observations on each variety is also from south to north, in accordance with the approximate latitude at which each observation was made.

PHENOLOGICAL OBSERVERS.

In the following list are included the names and post-office addresses of the fruit growers who have furnished the phenological data presented in this bulletin:

List of observers who have furnished the phenological data included in this bulletin.

NORTH CAROLINA.

Observer's No.	Grower.	Post-office.	County.
1	J. C. Cowan	Asheville	Buncombe.
2	T. P. Gaston	Candler	Do.
3	F. B. Barnhardt	Concord	Cabarrus.
4	J. A. Dula	Lenoir	Caldwell.
5	J. Hatley	Sawmill	Do.
6	J. S. Breece	Fayetteville	Cumberland.
7	M. L. Furr	Mount Holly	Gaston.
8	J. J. Phoenix	Greensboro	Guilford.
9	John Farrior	Waynesville	Haywood.
10	G. D. Green	do	Do.
10*a*	do	do	Do.
10*b*	do	do	Do.
10*c*	do	do	Do.
10*d*	do	do	Do.
11	C. Oates	Bear Wallow	Henderson.
12	J. F. Livingston	Fletcher	Do.
13	Mark Moore	Horseshoe	Do.
14	J. D. Woody	Wilmington	New Hanover.
15	W. T. Lindsey	Tryon	Polk.
15*a*	J. F. Davenport	Cherry	Washington.
16	J. L. Kincaid	Boone	Watauga.
17	C. G. Hodges	Sands	Do.

List of observers who have furnished the phenological data included in this bulletin—Con.

VIRGINIA.

Observer's No.	Grower.	Post-office.	County.
18	J. E. Smith	Cismont	Albemarle.
19	Walter Whately	Crozet	Do.
20	J. W. Apperson	Yancey Mills	Do.
21	T. J. Cunningham	Amherst	Amherst.
22	W. F. Gilkeson	Fishersville	Augusta.
23	H. F. Deffenbaugh	Staunton	Do.
24	J. D. Keeler	Bedford City, R. F. D	Bedford.
25	J. D. Lowry	do	Do.
26	J. F. Deboe	Bodycamp	Do.
27	W. H. Taylor	Colemans Falls	Do.
28	T. J. Holdren	Thaxton, R. F. D	Do.
29	M. L. Hatcher	Penicks, R. F. D	Do.
30	R. L. Dearing	Stewartsville	Do.
31	C. E. Layman	Troutville	Botetourt.
32	E. W. Byrd	Berryville	Clarke.
33	Hampton Agricultural and Normal Institute.	Hampton	Elizabeth City.
34	E. B. Whaley	Pender	Fairfax.
35	J. A. McLaughlin	Morrisville	Fauquier.
36	Joseph Wetsel	Wetsels	Greene.
37	A. B. Davis	Purcellville	Loudon.
38	H. L. Price	Blacksburg	Montgomery.
39	J. C. Carmody	Christiansburg	Do.
40	J. J. Shoemaker	do	Do.
41	W. B. MacGregor	Avon	Nelson.
42	Withers Massie	Massies Mill	Do.
43	R. L. Hughes	Nellysford	Do.
44	J. E. Purvis	Oakridge	Do.
44*a*	W. M. Boyd	Roseland, R. F. D	Do.
45	James Dickie	do	Do.
46	E. W. Rogers	Jennings	Nottoway.
47	Geo. W. Via	Woolwine	Patrick.
48	J. B. Johnson	Manassas	Prince William.
49	R. C. Booth	Dublin	Pulaski.
50	C. H. Constable	Warsaw	Richmond.
51	J. Coles Terry	Bent Mountain	Roanoke.
52	E. L. Wright	Vinton	Do.
53	W. J. Cowger	Dayton	Rockingham.
54	G. A. Copp	Strasburg	Shenandoah.
55	J. H. Pifer	do	Do.
56	L. B. Moore	Arco	Warren.

MARYLAND.

Observer's No.	Grower.	Post-office.	County.
57	Saml. Garner	Annapolis	Anne Arundel.
58	Jesse Smith	Linwood	Carroll.
59	Geo. Balderston	Colora	Cecil.
60	W. R. Grosh	Elkton	Do.
60*a*	do	do	Do.
61	J. M. Andrews	Hurlock	Dorchester.
62	C. L. Vail	Forest Hill	Harford.
63	Thomas Tobin	Harford Furnace	Do.
64	L. E. Hollingsworth	Joppa	Do.
65	J. S. Harris	Worton, R. F. D	Kent.
66	F. H. Harper	Stillpond	Do.
67	W. S. Maxwell	do	Do.
68	R. B. Thomas	Ednor	Montgomery.
69	W. I. Walker	Millington	Queen Anne.
70	Frisby Smith	Hancock	Washington.
71	F. E. Matthews	Pocomoke City	Worcester.

DELAWARE.

Observer's No.	Grower.	Post-office.	County.
72	F. C. Bancroft	Camden	Kent.
73	C. G. Brown	do	Do.
74	E. G. Packard	Dover	Do.
75	John Heyd	Felton	Do.
76	F. M. Soper	Magnolia	Do.
77	S. H. Derby	Woodside	Do.
78	G. B. Graeff	Bridgeville	Sussex.

List of observers who have furnished the phenological data included in this bulletin—Con.

NEW JERSEY.

Observer's No.	Grower.	Post-office.	County.
79	T. Chalmers	Folsom	Atlantic.
80	A. Hansell	Burlington	Burlington.
81	W. P. Pray	Dobbins	Do.
82	J. S. Collins	Moorestown	Do.
83	S. C. De Cou	do	Do.
84	G. L. Gillingham	do	Do.
85	A. L. Ritchie	Riverton	Do.
86	H. G. Taylor	do	Do.
87	H. L. Sabsovich	Woodbine	Cape May.
88	G. W. Gould	Montclair	Essex.
89	A. T. Repp	Glassboro	Gloucester.
90	C. G. Kirby	Mullica Hill	Do.
91	S. S. Budd	Thorofare	Do.
92	J. F. Brown	Princeton	Mercer.
93	H. E. Hale	do	Do.
94	I. J. Blackwell	Titusville	Do.
95	J. T. Robbins	Allentown	Monmouth.
96	W. H. Reid	Tennet	Do.
97	C. M. Rorer	Cassville	Ocean.
98	W. H. Skillman	Bellemead	Somerset.
99	A. F. Randolph	Boundbrook	Do.
100	W. J. Logan	Somerville	Do.
101	W. S. Little	Sussex	Sussex.
102	A. A. Miller	do	Do.
103	H. B. De Kay & Son	Vernon	Do.
104	M. E. Vass	Blairstown	Warren.

TABLE IV.—*Phenological records—Apples.*

ARKANSAS. Synonym: *Mammoth Black Twig.*

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
		° ′														
33	Virginia	37 0	5	SW.	Sandy loam	1903	7	Apr. 10	Apr. 18	Apr. 5	Apr. 25	June –	....	Oct. 27	....	
33	....do	37 0	5	SW.	....do	1904	8	Apr. 22	Apr. 30	Apr. 20	Apr. 5	June 23	Sept. 15	Oct. 17	Oct. 1	Oct.
38	....do	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 26	May 3	Apr. 8	Apr. 10	....	....	Sept. 24	....	....
38	....do	37 15	2,170	NW.	....do	1903	14	Apr. 10	Apr. 18	Apr. 5	Mar. 27	....	Oct. 1	Sept. 14	....	Mar.
38	....do	37 15	2,170	NW.	....do	1904	15	May 2	May 7	May 16	Apr. 19	June 20	....	Oct. 15	....	....
28	....do	37 20	1,000	N.	Sandy loam	1904	5	May 10	May 16	May 7	....	....	Oct. 20	....	Oct. 20	Late.
28	....do	37 20	1,000	N.	....do	1907	8	Mar. 27	Apr. 24	Mar. 7	Mar. 20	June 18	Oct. 8	....	Oct. 25	Do.
31	....do	37 25	1,400	NW.	Gravelly loam	1902	6	Apr. 20	...do	Apr. 8	Apr. 20	July –	Sept. 25	....	Oct. –	Do.
54	....do	39 0	1,000	NE.	Sandy loam	1903	10	Apr. 10	Apr. 22	Apr. 5	Apr. 1	June 10	Oct. 1	....	Dec. 6	June.
68	Maryland	39 10	550	S.	Porous clay	1906	9	Apr. 19	Apr. 30	May 10	Apr. 14	....	Oct. 10	Oct. 12	Jan. 1	Do.
90	New Jersey	39 45	125	SW.	Gravelly	1907	10	May 6	May 12	Apr. 21	....	....	....	....	....	Late.
83	....do	39 55	50	None.	Sandy	1906	......	Apr. 24	May 8	....	....	....	....	....	....	....
83	....do	39 55	50	None.	....do	1907	......	May 6	May 3	....	....	....	....	....	....	....

BALDWIN.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
4	North Carolina	35 50	1,200	S.	Sandy loam	1904	20	Apr. 15	May 1	....	....	....	Sept. –	....	Aug. –	Sept.
4	....do	35 50	1,200	S.	....do	1905	......	...do	....	....	....	....	....	....	...do	....
47	Virginia	36 45	1,600	S.	Porous loam	1905	10	May 1	May 10	May 1	....	....	....	....	....	....
38	....do	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 2	Apr. 18	Apr. 8	....	....	Oct. 14	....	....
38	....do	37 15	2,170	NW.	....do	1903	14	Apr. 16	Apr. 26	Apr. 5	Mar. 27	....	Sept. 15	Sept. 14	Oct. 1	Nov.
38	....do	37 15	2,170	NW.	....do	1904	15	....	....	May 16	Apr. 22	June 20	....	Oct. 15	....	....
24	....do	37 20	1,200	SE.	Porous loam	1903	10	Apr. 4	Apr. 10	Apr. 6	Apr. 12	....	Sept. 10	....	Aug. 1	Dec.
27	....do	37 30	1,000	NE.	Clay loam	1902	26	Apr. 18	Apr. 21	Mar. –	Apr. 9	....	Sept. 20	Nov. –	Oct. –	Do.
36	....do	38 15	650	......	Sandy loam	1902	18	...do	...do	May 3	Apr. 20	....	....	Oct. 17	....	....
53	....do	38 25	1,400	W.	Gravelly loam	1903	17	Apr. 11	Apr. 20	....	Apr. 9	....	Sept. –	....	Nov. –	Jan.
53	....do	38 25	1,400	W.	....do	1904	18	Apr. 20	Apr. 26	....	Apr. 3	....	...do	Oct. –	Sept. –	Do.
53	....do	38 25	1,400	W.	....do	1906	20	Apr. 26	May 2	May 11	Apr. 17	....	...do	Oct. 12	...do	Dec.
35	....do	38 30	400	NE.	Cecil clay	1902	5	May 4	May 8	Apr. 15	Apr. 16	Aug. 22	....	Oct. 22	....	....
35	....do	38 30	400	NE.	....do	1903	6	....	....	Apr. 5	Mar. 22	Aug. 1	....	Oct. 18	....	....
35	....do	38 30	400	NE.	....do	1904	7	....	....	Apr. 23	Apr. 7	July 19	....	Sept. 23	....	....
35	....do	38 30	400	NE.	....do	1905	8	Apr. 17	Apr. 22	Apr. 20	Mar. 31	July 10	Sept. 10	Oct. 13	....	....
35	....do	38 30	400	NE.	....do	1906	9	....	....	May 10	Apr. 16	July 26	....	Oct. 12	....	....
48	....do	38 45	375	SE.	Porous loam	1903	15	Apr. 9	Apr. 12	Apr. 5	Apr. 15	June 30	Aug. 20	Oct. 25	Oct. 20	Nov.
48	....do	38 45	375	SE.	....do	1905	17	Apr. 20	Apr. 24	....	Apr. 20	....	....	....	....	....

TABLE IV.—*Phenological records—Apples*—Continued.

BALDWIN—Continued.

Observer number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking.)	Date first fall frost.	Date fit for use.	Keeps until—
48	Virginia	38	45	375	SE.	Porous loam	1906	33	Apr. 25	Apr. 27	May 11	May 1			Oct. 11	Aug. 20	Nov.
48	do	38	45	375	SE.	do.	1907		Apr. 26	Apr. 28	Apr. 20			Sept. 20	Oct. 13		Do.
56	do	38	50	950	NW.	Porous clay	1907	10	Apr. 15	Apr. 25	Apr. 10	Apr. 15	Apr. 25	Sept. 1			Jan.
54	do	39	0	1,000	NE.	Porous loam	1902	8	Apr. 24	Apr. 29	Apr. 14	Apr. 16	June 15	Sept. 20		Sept. 20	
54	do	39	0	1,000	NE.	do.	1903	9	Apr. 18	Apr. 24	Apr. 5	Apr. 1	June 10	Sept. 10		do.	Dec.
54	do	39	0	1,000	NE.	do.	1904	10	May 6	May 10	Apr. 20	Apr. 30	do.				
54	do	39	0	1,000	NE.	do.	1905	11	Apr. 24	Apr. 29	Apr. 19	Apr. 11	do.	Sept. 20			
54	do	39	0	1,000	NE.	do.	1906	18	Apr. 26	Apr. 30	May 8	Apr. 18	do.	Sept. 25		Oct. 1	Mar.
54	do	39	0	1,000	NE.	do.	1907	19	Apr. 25	do.	Apr. 23	Apr. 3	June 15	Oct. 1		Dec. –	June.
72	Delaware	39	10	70	None.	Sandy loam	1902	30	do.	Apr. 28				Sept. 30	Oct. 20	Nov. 1	
73	do	39	10	70	None.	do.	1902	20	Apr. 28	May 4		Apr. 12		Sept. 1		Sept. 15	Nov.
64	Maryland	39	25	225		Stony loam	1905	40	Apr. 23	Apr. 28	Apr. 19	Apr. 23	Sept. 1	Sept. 15	Oct. 19	Sept. 1	Jan.
64	do	39	25	225		do.	1906	60	Apr. 29	May 3	May 10	Apr. 30	Aug. 30		Oct. 11		
63	do	39	30	150	N.	Clay loam	1907	20	May 1	May 8	May 12	Apr. 16	Aug. 6	Oct. 8	Oct. 15	Sept. 15	Mar.
62	do	39	35	500	E.	Loam	1905	45	Apr. 26	May 4				Oct. 15		Dec. 15	
62	do	39	35	500	E.	do.	1906		Apr. 28	May 2	May 11			Oct. 1			
60	do	39	35	75	SW.	Heavy loam	1902	10	Apr. 30	do.	May 28	Apr. 25	July 15	Sept. 15	Nov. 15	Late	
60	do	39	35	75	SW.	do.	1904	12	May 7	May 10	May 11	Apr. 30	June 29	Oct. 5	Sept. 17		
79	New Jersey	39	35	90	NW.	Gravelly loam	1902	50	Apr. 24	Apr. 29	Apr. 15	Apr. 20		Sept. 15	Oct. 22	Sept. 15	
89	do	39	40	150	None.	Porous loam	1904	27	May 6	May 10	Apr. 17	May 2	June 15	do.	Sept. 25	Jan. 1*a*	
90	do	39	45	125	SW.	Gravelly	1907	10	do.	do.	Apr. 21						
91	do	39	50	150			1906	35	Apr. 22	May 1		Apr. 14	July 20	Oct. 15		Sept. 10	Feb.
83	do	39	55	50	None.	Sandy loam	1902	20	Apr. 24	Apr. 30							
80	do	40	5	50	N.	Porous loam	1904	35	May 7	May 9	Apr. 24		June 1	Sept. 25	Oct. 10	Sept. 10	Apr.
80	do	40	5	50	N.	do.	1905	50	Apr. 30	May 5	Apr. 19	Apr. 20	June 7	Sept. 28	Oct. 15		Do.
80	do	40	5	50	N.	do.	1907	40	May 6	May 14	Apr. 20	Apr. 10	June 20	Oct. 4			
96	do	40	15	90	N.&S.	Clay loam	1904	25	May 9	do.		May 6		Sept. 14	Sept. 17	Sept. 14	Jan.
96	do	40	15	90	N.&S.	do.	1905	26	May 1	May 8		Apr. 20		Sept. 12	Oct. 18	Sept. 15	Do.
96	do	40	15	90	N.&S.	do.	1906	27	do.	do.		do.		do.		Sept. 12	Do.
92	do	40	15	200	S.	do.	1906	35	Apr. 26	May 4	May 10			Oct. 15	Oct. –	Oct. 15	Feb.
92	do	40	15	200	S.	do.	1907	36	May 10	May 15	May 22	Apr. 27	June 12	Oct. 1		Dec. –	Do.
94	do	40	20	125	SW.	Sandy loam	1902	38	Apr. 29	May 4	Apr. 28	Apr. 20	June 27	do.	Oct. 10	Sept. 20	Sept.
94	do	40	20	125	SW.	do.	1904	40	May 7	May 11		Apr. 28	July 16	Sept. 1	Sept. 20	Sept. 10	Do.
94	do	40	20	125	SW.	do.	1905	41	May 2	May 7	Apr. 19			Sept. 15		Sept. 1	Oct.
94	do	40	20	125	SW.	do.	1906	42	do.	May 9	May 12	Apr. 20	June 5	Sept. 20			
94	do	40	20	125	SW.	do.	1907	43	May 13	May 16		Apr. 27	July 4	do.	Oct. 20	Oct. –	Oct.
99	do	40	35	40	NW.	do.	1907		May 10		May 12	May 1		Oct. 15	Oct. 5		Jan.
100	do	40	35	600	N.	Clay loam	1903	19	Apr. 22			Apr. 7					

100	do.	40	35	600	W.	do.	1904	20	May 8	May 16	Apr. 22	May 1					
88	do.	40	50	500	E.	Sandy loam	1907	16	do.	May 12	Apr. 25	May 14		Oct. 15	Oct. 10	Nov. 25	Mar.
104	do.	41	0	600	None.	Clay loam	1904	12	May 11	May 16	Apr. 23	May 2	July 2	Oct. 8	Sept. 22	Jan. –	Do.
104	do.	41	0	600	None.	do.	1905	14	May 7	May 11	Apr. 24	Apr. 25	July 3	Oct. 5	Oct. 22	Dec. –	Apr.
104	do.	41	0	600	None.	do.	1906	15	May 9	May 14	May 11	Apr. 22	July 2	Oct. 8	Oct. 12	do.	Mar.
104	do.	41	0	600	None.	do.	1907	16	May 15	May 20	May 12	Apr. 27	July 3	Oct. 15	Oct. 25	do.	Apr.
101	do.	41	10	550	SE.	Gravelly	1904	11	May 8	May 18	Apr. 23	Apr. 30			Sept. 22		
102	do.	41	10	800	None.	Sandy loam	1904	25	May 12	do.							
102	do.	41	10	800	None.	do.	1905	26	May 7	May 12						Dec. –	Apr.
103	do.	41	15	400	SW.	do.	1904		May 12	May 18	May 5			Sept. 1			

BEN DAVIS.

6	North Carolina	35	5	200	None.	Sandy	1902		Apr. 6	Apr. 18		Mar. 23					
6	do.	35	5	200	None.	do.	1904		Mar. 23	Mar. 31							
7	do.	35	20	700	None.	Loam	1905	10	Mar. 25	Apr. 5	Apr. 17	Mar. 18			Oct. 11		
11	do.	35	25	1,990	SE.	Porous loam	1904	15	Apr. 30	May 5	Apr. 21	May 5		Sept. 23	Oct. 24	Nov. 1	Jan.
11	do.	35	25	1,990	SE.	do.	1905	12	May 1	May 10	May 6	May 10		Sept. 5	Oct. 18		
11	do.	35	25	1,990	SE.	do.	1906	20	Apr. 12	Apr. 20	May 10	Apr. 5		Oct. 10	Oct. 10	Nov. 1	Jan.
11	do.	35	25	1,990	SE.	do.	1907	9	Apr. 4	Apr. 30	Apr. 2	Apr. 20					Mar.
12	do.	35	25	2,128	W.	do.	1902	18	Apr. 26	May 2	Apr. 5	Apr. 23	July 1	Sept. 20	Oct. 15	Oct. 1	Feb.
12	do.	35	25	2,128	W.	do.	1903	19	Apr. 11	Apr. 16	Apr. 6	Apr. 24					
12	do.	35	25	2,128	W.	do.	1904	20	Apr. 20	May 2	Apr. 11	May 14	Aug. 8	Oct. 1	Oct. 15	Nov. 15	Feb.
12	do.	35	25	2,128	W.	do.	1905	21	Apr. 8	Apr. 16	Apr. 7	Apr. 23	Aug. 1	Sept. 25	Oct. 14	Nov. 1	Jan.
2	do.	35	30	2,900	E.	Clay loam	1904	8	Apr. 17	Apr. 28	Apr. 20	Apr. 7			do.		
2	do.	35	30	2,900	E.	do.	1905	9	Apr. 5	Apr. 13	Apr. 18	Apr. 3	July 24	Nov. 12	Oct. 17		
10	do.	35	30	2,875	SW.	do.	1902	14	Apr. 29	May 8	Apr. 1	May 6	July 28	Oct. 15	Oct. 15	Dec. 15	Mar.
10	do.	35	30	2,875	SW.	do.	1903	7	Apr. 1	Apr. 12	Apr. 28	Apr. 5	July 15	Oct. 20	Oct. 25	Dec. 25	Apr.
10	do.	35	30	2,875	SW.	do.	1904	8	Apr. 16	Apr. 25	Apr. 1	Mar. 23	June 30	Oct. 15	Oct. 16	Nov. 1	Feb.
10	do.	35	30	2,875	SW.	do.	1905	9			Mar. 10	Mar. 28	July 2	Oct. 20		Dec. 15	Do.
10a	do.	35	30	3,300	NE.	Porous loam	1902	6	Apr. 21	Apr. 27	Apr. 15	Apr. 24	July 30	do.	Oct. 5	Dec. 20	Mar.
10b	do.	35	30	3,500	SE.	do.	1902	12	May 1	May 10	Apr. 20	May 7	July 29	do.	Oct. 3	do.	Do.
10c	do.	35	30	4,000	NE.	Clayey loam	1902	9	do.	May 8	Apr. 25	May 9	July 30	do.	do.	Feb. –	Do.
10d	do.	35	30	4,500	SE.	Sandy loam	1902	12	Apr. 25	May 3	Apr. 22		do.	Oct. 25	Oct. 1	Dec. 20	Feb.
10d	do.	35	30	4,500	SE.	do.	1903	13	May 1	May 12	Apr. 28	May 4	July 18	Oct. 10	Oct. 5	Dec. 10	May.
1	do.	35	35	2,300	S.	Loam	1904	4	Apr. 15	Apr. 28	Apr. 20	Apr. 3			Oct. 15		
17	do.	36	15	3,000	SE.	Clay loam	1904	8	Apr. 30	May 8	May 3	May 5		Oct. 7	Oct. 11	Jan. 15	May.
47	Virginia	36	45	1,700	SE.	Black loam	1905		Apr. 15	May 1	May 1			Sept. 20		Oct. 20	Apr.
33	do.	37	0	5	None.	Sandy loam	1904	8	Apr. 21	Apr. 30	Apr. 20	Apr. 5	June 23	Aug. 20	Oct. 17		
49	do.	37	5				1907	11	Apr. 23	May 3	do.	Apr. 28		Oct. 5	Oct. 15	Sept. 15	May.
39	do.	37	10	2,000	NW.	Dark loam	1902	10	Apr. 26	May 1	May 18	Apr. 20		Oct. 10	Sept. 10	Dec. 25	Mar.
40	do.	37	10	2,400	SE.	Porous loam	1907	8	Apr. 15	Apr. 30		Apr. 5					
26	do.	37	15	900	N.	Sandy loam	1902	15	Apr. 19	Apr. 25							
26	do.	37	15	900	N.	do.	1903	16	Apr. 4	Apr. 11				Sept. 10		Sept. 15	Nov.
38	do.	37	15	2 170	NW.	Limestone clay	1902	13	Apr. 26	May 3	Apr. 18	Apr. 12		Sept. 25	Sept. 14		
38	do.	37	15	2,170	NW.	do.	1903	14	Apr. 25	Apr. 30	Apr. 5	Mar. 30		Sept. 30	do.		
38	do.	37	15	2,170	NW.	do.	1904	15	May 7	May 10	May 16	Apr. 23	June 22		Oct. 15		
28	do.	37	20	1,000	N.	Sandy loam	1904	8	May 15		May 7			Oct. 20		Oct. 20	Late.

a From cold storage.

TABLE IV.—*Phenological records—Apples*—Continued.

BEN DAVIS—Continued.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking.)	Date first fall frost.	Date fit for use.	Keeps until—
		°	′														
28	Virginia	37	20	1,000	N.	Sandy loam	1905	9	Apr. 12	Apr. 20	Mar. 28	Apr. 3	June 15	Sept. 24	....	Oct. 5	Late.
28	..do	37	20	1,000	N.	..do	1906	10	Apr. 17	Apr. 23	May 29	Apr. 2	July 10	....	Nov. 20	....	....
25	..do	37	20	1,000	SE.	Cecil clay	1902	10	Apr. 15	Apr. 20	May 20	Apr. 15	July 15	Oct. 15	Oct. 20	Jan. –	Mar.
25	..do	37	20	1,000	SE.	..do	1903	11	Apr. 20	May 1	Apr. 20	Apr. 20	July 20	Oct. 10	Oct. 15	Dec. –	Do.
25	..do	37	20	1,000	SE.	..do	1904	12	May 1	May 10	May 5	May 1	July 10	..do	Oct. 10	..do	Do.
25	..do	37	20	1,000	SE.	..do	1905	13	Apr. 25	May 5	Apr. 15	Apr. 25	July 20	Oct. 20	Oct. 20	..do	Do.
29	..do	37	20	1,000	SE	..do	1903	4	Apr. 4	Apr. 25	Apr. 6	Apr. 15	....	Sept. 15	....	Sept. –	Jan.
31	..do	37	25	1,400	NW.	Porous loam	1902	6	Apr. 21	Apr. 24	Apr. 8	Apr. 21	July –	Sept. 25	....	Nov. 4	Late.
27	..do	37	30	1,000	NE.	Clay loam	1902	26	Apr. 19	Apr. 22	Mar. –	Apr. 9	....	Sept. 20	Nov. –	Oct. –	Dec.
27	..do	37	30	1,000	NE.	..do	1904	38	Apr. 18	..do	Apr. 22	....	....	Sept. 15	Oct. 26	Sept. –	Nov.
44	..do	37	45	625	SW.	Loam	1904	12	Apr. 22	Apr. 26	Apr. *a*	Apr. 4	June 15	....	....	....	....
50	..do	37	55	200	E.&W.	Sandy loam	1902	15	Apr. 17	Apr. 23	Apr. 9	Apr. 10	....	Oct. –	Oct. 30	Oct. –	Dec.
50	..do	37	55	200	E.&W.	..do	1903	16	Mar. 29	Apr. 3	....	Apr. 5	....	..do	....	..do	....
50	..do	37	55	200	E.&W.	..do	1904	17	Apr. 20	Apr. 25	Apr. 6	Apr. 25	....	Oct. 20	Sept. 7	..do	....
50	..do	37	55	200	E.&W.	..do	1905	18	Apr. 12	Apr. 16	Apr. 19	Apr. 16	....	Oct. 1	Oct. 22	..do	Oct.
50	..do	37	55	200	E.&W.	..do	1906	19	Apr. 15	Apr. 25	May 11	Apr. 25	....	Oct. 20	....	Nov. –	Dec.
71	Maryland	38	5	20	SE.	Clay loam	1902	8	....	Apr. 29	....	Apr. 12	....	..do	....	Nov. –	Do.
19	Virginia	38	5	900	S.	Cecil clay	1905	14	Apr. 14	Apr. 22	Apr. 19	Apr. 1	....	Sept. 1	Oct. 7	....	....
23	..do	38	10	1,400	N.	Porous loam	1907	8	Apr. 23	May 1	May 18	..do	July 10	Oct. 8	Oct. 13	Dec. –	May.
22	..do	38	10	1,200	NE.	..do	1907	20	..do	Apr. 30	May 22	Mar. 28	....	Oct. 15	Oct. 9	Feb. 1	Apr.
36	..do	38	15	650	....	Sandy loam	1902	15	Apr. 19	Apr. 24	May 3	Apr. 18	....	Oct. 17	....	....	....
53	..do	38	25	1,400	W.	Porous loam	1902	16	Apr. 28	May 2	....	Apr. 17	....	Sept. 30	....	Nov. –	Feb.
53	..do	38	25	1,400	W.	..do	1903	17	Apr. 9	Apr. 20	....	Apr. 9	....	Oct. –	....	Dec. –	Do.
53	..do	38	25	1,400	W.	..do	1905	19	Apr. 22	Apr. 27	Apr. 24	Apr. 4	....	Oct. 1	Oct. –	Oct. –	Do.
53	..do	38	25	1,400	W.	..do	1906	20	Apr. 27	May 3	May 11	Apr. 18	July –	..do	Oct. 8	..do	Do.
35	..do	38	30	400	NE.	Clayey	1902	15	Apr. 22	Apr. 26	Apr. 15	Apr. 9	Aug. 18	Sept. 26	Oct. 22	....	Mar.
35	..do	38	30	400	NE.	..do	1903	16	Apr. 2	Apr. 12	Apr. 5	Mar. 21	Aug. 6	Oct. 1	Oct. 18	....	Do.
35	..do	38	30	400	NE.	..do	1904	17	Apr. 30	May 5	Apr. 23	Apr. 8	July 23	Sept. 26	Sept. 23	....	Do.
35	..do	38	30	400	NE.	..do	1905	18	Apr. 18	Apr. 20	Apr. 20	Apr. 30	July 18	....	Oct. 13	....	Do.
35	..do	38	30	400	NE.	..do	1906	19	Apr. 22	Apr. 28	May 10	Apr. 9	July 28	....	Oct. 12	Sept. 1	Do.
61	Maryland	38	40	45	None.	Sandy loam	1907	15	Apr. 15	..do	....	....	....	....	....	....	....
78	Delaware	38	45	50	SE.	..do	1904	21	Apr. 29	May 4	Apr. 22	Apr. 13	....	....	....	....	....
34	Virginia	38	45	300	W.	Clay loam	1902	13	Apr. 18	....	May 30*b*	....	....	....	....	....	....
48	..do	38	45	375	SE.	Porous loam	1903	15	Apr. 8	Apr. 11	Apr. 5	Apr. 15	July 2	Sept. 15	Oct. 25	Jan. –	Mar.
48	..do	38	45	375	SE.	..do	1905	17	Apr. 23	Apr. 26	Apr. 19	Apr. 21	....	....	....	....	....
48	..do	38	45	375	SE.	..do	1906	30	Apr. 26	Apr. 28	May 11	Apr. 29	....	....	Oct. 11	Sept. 20	Feb.
48	..do	38	45	375	SE.	..do	1907	....	Apr. 22	Apr. 25	Apr. 20	....	....	....	Oct. 13	....	....

56	....do	38	50	950	NW.	Clay loam	1907	10	Apr. 20	Apr. 30	Apr. 10	Apr. 20	....	Sept. -	....	Jan. -	Apr.
54	....do	39	0	1,000	NE.	Porous loam	1902	14	Apr. 23	Apr. 26	Apr. 14	Apr. 14	June 15	Oct. 1	....	Nov. -	Late.
54	....do	39	0	1,000	NE.	....do	1903	15	Apr. 6	Apr. 20	Apr. 15	Mar. 27	June 10	...do	....	Dec. -	June.
54	....do	39	0	1,000	NE.	....do	1904	16	May 2	May 7	Apr. 20	Apr. 21	...do	....	....	....	....
54	....do	39	0	1,000	NE.	....do	1905	17	Apr. 17	Apr. 24	Apr. 19	Apr. 3	...do	Sept. 20	....	Dec. -	....
54	....do	39	0	1,000	NE.	....do	1906	18	Apr. 24	Apr. 29	May 8	Apr. 17	...do	Oct. 1	....	Oct. -	Apr.
54	....do	39	0	1,000	NE.	....do	1907	19	Apr. 20	Apr. 25	Apr. 23	Mar. 29	June 15	...do	....	Dec. -	June.
55	....do	39	0	600	E.	....do	1907	14	Apr. 21	Apr. 24	May 9	Mar. 27	....	...do	Oct. 10	Mar. -	May.
57	Maryland	39	0	75	None.	Sandy	1907	15	Apr. 27	May 6	Apr. 18	Apr. 6	....	....	....	....	....
68	....do	39	10	550	S.	Clay loam	1906	9	Apr. 21	May 2	May 10	Apr. 17	....	Oct. 1	Oct. 12	....	....
32	Virginia	39	10	500	NW.	Red loam	1905	11	Apr. 23	Apr. 26	Apr. 18	Apr. 1	Apr. 18	Oct. 4	....	Dec. -	Mar.
32	....do	39	10	500	NW.	....do	1906	12	Apr. 26	Apr. 30	Apr. 25	Apr. 20	June 15	Oct. 1	Oct. 15	Jan. -	Do.
37	....do	39	10	600	NW.	Clay loam	1903	17	Apr. 17	Apr. 23	....	....	....	....	....	....	....
87	New Jersey	39	15	40	SW.	Sandy loam	1902	10	Apr. 30	May 7	....	Apr. 24	....	....	....	....	....
65	Maryland	37	20	75	None.	Gravelly loam	1902	7	Apr. 25	Apr. 28	....	Apr. 7	....	Oct. 15	Nov. -	Dec. -	....
65	....do	37	20	75	None.	....do	1903	8	Apr. 15	Apr. 20	....	Apr. 1	....	....	....	Nov. -	Jan.
64	....do	39	25	225	SE.	Stony loam	1905	15	Apr. 25	Apr. 30	Apr. 19	Apr. 23	....	Oct. 15	Oct. 19	...do	Do.
64	....do	39	25	225	SE.	....do	1906	16	Apr. 29	May 1	May 10	May 1	....	....	Oct. 11	....	....
64	....do	39	25	225	SE.	....do	1907	17	May 1	May 10	May 5	Apr. 28	....	....	Oct. 17	....	....
63	....do	39	30	150	N.	Clay loam	1907	20	...do	May 6	May 12	Apr. 24	Aug. 6	Oct. 14	Oct. 14	Sept. 16	Mar.
62	....do	39	35	500	E.	Loam	1905	25	Apr. 26	May 4	May 5	Apr. 28	....	....	Oct. 17	....	....
89	New Jersey	39	40	150	None.	Porous loam	1904	25	May 8	May 12	Apr. 17	May 4	June 15	Oct. 1	Sept. 25	....	Apr.[c]
90	....do	39	45	125	SW.	Gravelly	1907	10	May 5	May 9	Apr. 21	....	....	....	....	....	....
91	....do	39	50	....	....	....	1906	3	Apr. 30	May 1	....	Apr. 14	July 20	Oct. 15	....	Oct. -	Apr.
82	....do	39	55	50	W.	Sandy loam	1902	6	Apr. 25	Apr. 30	....	....	....	Oct. 1	....	Sept. -	Dec.
84	....do	39	55	50	W.	Heavy loam	1902	20	...do	...do	Apr. 16	Apr. 20	Sept. 15	...do	Oct. 10	Dec. -	Feb.
84	....do	39	55	50	W.	....do	1903	21	Apr. 22	Apr. 28	May 2	Apr. 10	Aug. 30	...do	Oct. -	Oct. -	Do.
84	....do	39	55	50	W.	....do	1904	22	May 7	May 17	....	Apr. 23	Aug. 1	...do	....	Nov. -	Mar.
92	....do	40	15	200	S.	Clay loam	1906	35	Apr. 23	Apr. 30	May 10	....	....	Oct. 15	Oct. -	Oct. -	Feb.
92	....do	40	15	200	S.	....do	1907	36	May 11	May 16	May 22	Apr. 27	June 12	Oct. 1	...do	Nov. -	Mar.
96	....do	40	15	90	N.&S.	....do	1904	21	May 9	May 14	....	May 6	....	Sept. 18	Sept. 17	Jan. -	Apr.
96	....do	40	15	90	N.&S.	....do	1905	22	May 2	May 9	Apr. -	Apr. 22	....	Oct. 13	Oct. 18	...do	Do.
96	....do	40	15	90	N.&S.	....do	1906	23	...do	May 3	Apr. 18	Apr. 24	....	Oct. 18	...do	Dec. -	Do.
94	....do	40	20	125	S.	Sandy loam	1904	......	May 6	May 11	....	Apr. 29	July 16	Oct. 1	Sept. 20	...do	Mar.
94	....do	40	20	125	S.	....do	1906	......	May 3	May 8	....	Apr. 20	June 5	Oct. 20	....	Oct. -	....
94	....do	40	20	125	S.	....do	1907	......	May 12	May 15	....	Apr. 26	July 4	....	....	....	....
98	....do	40	30	600	S.	Red shale	1905	14	May 3	May 12	Apr. 16	Apr. 28	....	Sept. -	Sept. -	....	Mar.
88	....do	40	50	500	E.	Sandy loam	1907	16	May 8	...do	Apr. 25	May 14	....	Oct. 15	Sept. 10	Nov. -	Do.
104	....do	41	0	600	None.	Clay loam	1904	12	May 10	May 14	Apr. 23	May 2	July 6	Oct. 20	Sept. 22	....	....
104	....do	41	0	600	None.	....do	1905	13	May 7	May 11	Apr. 24	Apr. 26	July 3	Oct. 12	Oct. 22	Feb. -	May.
104	....do	41	0	600	None.	....do	1906	14	May 9	May 14	May 11	...do	June 30	Oct. 13	Oct. 12	Mar. -	Do.
104	....do	41	0	600	None.	....do	1907	15	May 16	May 21	May 12	Apr. 27	July 1	Oct. 26	Oct. 25	...do	Do.
101	....do	41	10	550	SE.	Gravelly	1904	11	May 7	May 18	Apr. 23	Apr. 28	....	....	Sept. 22	....	....

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[a] Frost did much damage to the fruit.

[b] Frost seriously injured the fruit.

[c] From cold storage.

TABLE IV.—*Phenological records Apples*—Continued.

BONUM.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
6	North Carolina	35 5	200	None.	Sandy	1902		Apr. 7	Apr. 17		Mar. 30			Sept. 14		
15	do	35 25	770	N.	do	1905	8	Apr. 2	Apr. 9	Apr. 18	Mar. 20	May 16		Oct. 22		
38	Virginia	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 3	Apr. 8	Apr. 15			Sept. 14		
31	do	37 25	1,400	NW.	Gravelly loam	1902	12	Apr. 20	Apr. 24	do	Apr. 21	July –	Aug. 15		Aug. 15	Oct.
48	do	38 45	375	SE.	Porous loam	1903	10	Apr. 8	Apr. 12	Apr. 5	Apr. 15		Sept. 1	Oct. 25		Dec.

BOUGH.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
72	Delaware	39 10	70	None.	Sandy loam	1902	30	Apr. 23	Apr. 27				July 5	Oct. 20	July 5	
96	New Jersey	40 15	90	N.&S.	Clay loam	1904	25	May 9	May 15		May 7		July 19	Sept. 17	July 25	
94	do	40 20	150	S.	Sandy loam	1902	38	Apr. 29	May 4	Apr. 28	Apr. 20	June 27	July 25	Oct. 10	July 20	
94	do	40 20	150	S.	do	1906		Apr. 30	do		Apr. 16	June 5	July 23	Oct. 14	Aug. 1	

CHENANGO.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
38	Virginia	37 15	2,170	NW.	Limestone clay	1903	12	Apr. 12	Apr. 21	Apr. 5	Mar. 27			Sept. 14		
38	do	37 15	2,170	NW.	do	1904	13	May 2	May 8	May 16	Apr. 16	June 25		Oct. 15		

COLTON.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
38	Virginia	37 15	2,170	NW.	Limestone clay	1903	14	Apr. 10	Apr. 28	Apr. 5	Mar. 27			Sept. 14		
38	do	37 15	2,170	NW.	do	1904	15	Apr. 30	May 11	May 16	Apr. 16	June 25		Oct. 15		
37	do	39 10	600	NW.	Clay loam	1903	17	Apr. 12	Apr. 17							

EARLY HARVEST.

6	North Carolina	35	5	200	None.	Sandy	1904	......	Mar. 22	Mar. 28	....	....	....	....	....	....	
7	do	35	20	700	None.	Loam	1905	10	Mar. 25	Mar. 31	Apr. 17	Mar. 15	....	....	Oct. 11		....
11	do	35	25	1,990	SE.	Porous loam	1904	15	Apr. 20	Apr. 28	Apr. 21	Apr. 25	....	June 20	Oct. 24	....	....
11	do	35	25	1,990	SE.	do	1905	10	do	May 1	May 6	May 6	....	July 20	Oct. 18	July 1	Aug.
11	do	35	25	1,990	SE.	do	1906	8	Apr. 15	Apr. 25	May 10	Apr. 8	....	June 20	....	June 20	....
11	do	35	25	1,990	SE.	do	1907	9	Mar. 30	Apr. 20	Apr. 20	Apr. 10	....	....	Oct. 13	....	....
12	do	35	25	2,100	W.	do	1902	12	Apr. 18	Apr. 24	Apr. 5	Apr. 16	July 1	July 10	Oct. 15	July 1	Aug.
12	do	35	25	2,100	W.	do	1903	18	Mar. 28	Apr. 6	Apr. 6	Apr. 8	....	....	....	....	....
12	do	35	25	2,100	W.	do	1904	19	Apr. 12	Apr. 20	Apr. 11	Apr. 21	July 26	July 18	Oct. 15	July 20	Aug.
12	do	35	25	2,100	W.	do	1905	20	Apr. 2	Apr. 10	Apr. 7	Apr. 12	July 15	July 14	Oct. 14	July 15	Do.
13	do	35	25	2,180	NE.	Clay loam	1905	16	Mar. 28	Apr. 20	Mar. 27	Mar. 25	....	....	Oct. 17	July 1	....
13	do	35	25	2,180	NE.	do	1907	17	Apr. 3	....	Apr. 15[a]	....	....	....	Oct. 15	....	....
2	do	35	30	2,900	E.	do	1904	......	Apr. 18	Apr. 28	Apr. 20	....	....	....	Oct. 14	....	....
2	do	35	30	2,900	E.	do	1905	......	Apr. 2	Apr. 12	Apr. 18	Apr. 21	July 20	July 1	Oct. 17	....	....
10	do	35	30	2,875	SW.	do	1902	......	Apr. 28	May 5	Apr. 1	May 4	July 30	July 25	Oct. 15	Aug. 1	Aug.
10a	do	35	30	4,500	SE.	Sandy loam	1903	12	May 1	May 10	Apr. 28	May 10	July 15	Aug. 15	do	Aug. 20	....
1	do	35	30	2,300	S.	Porous loam	1902	10	Apr. 20	Apr. 26	Apr. 18	Apr. 12	....	....	do	....	Aug.
1	do	35	30	2,300	S.	do	1904	12	Apr. 12	Apr. 28	Apr. 20	Apr. 3	July 1	....	do	....	....
1	do	35	30	2,300	S.	do	1905	13	Apr. 5	Apr. 15	Apr. 16	Mar. 27	....	....	Oct. 16	....	....
1	do	35	30	2,300	S.	do	1906	10	Apr. 20	Apr. 26	Apr. 18	Apr. 12	....	....	Oct. 15	....	....
15a	do	35	45	6	None.	Sandy	1907	......	Apr. 4	Apr. 22	Mar. 15	Apr. 5	Apr. 19	....	Oct. 20	....	....
4	do	35	50	1,200	S.	Sandy loam	1904	12	Apr. 15	....	....	....	....	....	....	July 1	Aug.
4	do	35	50	1,200	S.	do	1905	13	do	May 1	Apr. 24	....	....	....	....	....	July.
16	do	36	10	3,250	S.	Clay loam	1904	18	May 8	May 15	Apr. 21	Apr. 26	July 5	....	Oct. 15	Aug. 10	Sept.
16	do	36	10	3,250	S.	do	1905	19	Apr. 23	May 1	May 16	Apr. 12	July 9	Aug. 10	Oct. 20	....	....
17	do	36	15	3,000	SE.	do	1904	12	Apr. 28	May 5	May 3	May 1	....	do	Oct. 11	July 25	Sept.
47	Virginia	36	45	1,700	SE.	Black loam	1905	15	Apr. 10	Apr. 20	May 1	....	....	Aug. 1	....	Aug. 1	Do.
33	do	37	0	5	SW.	Sandy loam	1903	7	....	....	Apr. 5	Mar. 23	....	July 1	Oct. 27	July 1	July.
33	do	37	0	5	SW.	do	1904	8	Apr. 13	Apr. 26	Apr. 20	Mar. 28	June 23	July 3	Oct. 17	July 8	Do.
40	do	37	10	2,400	None.	Clay loam	1907	8	Apr. 7	Apr. 18	Apr. 1	....	....	....	....	....	....
[illegible]	do	37	10	2,000	NW.	Loam	1902	4	Apr. 24	Apr. 28	May 18	Apr. 20	....	....	Sept. 10	July 25	Aug.
26	do	37	15	900	N.	Clay loam	1903	......	Apr. 1	Apr. 7	....	....	June 15	July 15	....	June 20	July.
46	do	37	15	500	S.	Sandy loam	1903	......	Mar. 30	....	....	....	....	....	....	do	Do.
38	do	37	15	2,170	NW.	Limestone clay	1903	13	Apr. 28	May 2	Apr. 18	Apr. 11	....	....	Sept. 14	....	....
38	do	37	15	2,170	NW.	do	1904	14	Apr. 12	Apr. 29	Apr. 5	Mar. 26	....	....	do	....	....
[illegible]	do	37	15	2,170	NW.	do	1905	15	....	....	May 16	Apr. 18	June 20	....	Oct. 15	....	....
[illegible]	do	37	20	950	SE.	Clay loam	1902	27	Apr. 12	Apr. 25	Apr. 1	Apr. 15	....	July 10	Oct. 27	July 1	....
[illegible]	do	37	20	950	SE.	do	1903	28	Apr. 2	Apr. 10	Apr. 6	Mar. 28	....	June 28	Nov. 2	July 10	....
28	do	37	20	1,000	N.	do	1904	6	May 5	May 10	May 7	Apr. 14	....	June 20	....	June 20	July.
28	do	37	20	1,000	N.	do	1906	8	Apr. 10	Apr. 16	Mar. 29	Apr. 2	June 19	....	Nov. 20	....	....
28	do	37	20	1,000	N.	do	1907	9	Apr. 13	Apr. 23	Mar. 7	Mar. 20	June 25	....	Nov. 4	July 16	Aug.
52	do	37	20	1,200	W.	....	1902	16	Apr. 16	Apr. 22	....	Apr. 7	....	....	....	....	....
29	do	37	20	1,000	......	Clay loam	1903	25	Mar. 25	Apr. 6	Apr. 6	Apr. 10	....	June 24	....	June 10	July.
31	do	37	25	1,400	NW.	do	1902	12	Apr. 19	Apr. 23	Apr. 8	Apr. 20	July –	June 15	....	June 15	Do.
44	do	37	45	625	SW.	Loam	1904	12	Apr. 24	....	Apr. –	Apr. 4	June 15	....	....	....	....
45	do	37	50	....	S.	do	1906	56	Apr. 12	Apr. 16	May 9	Apr. 5	....	....	Oct. 10	....	....
50	do	37	55	200	E.&W.	Sandy loam	1902	15	Apr. 17	Apr. 23	Apr. 9	May 10	....	July –	Oct. 30	July –	Aug.

[a] Frost killed the entire crop.

TABLE IV.—*Phenological records—Apples*—Continued.

EARLY HARVEST—Continued.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
		°	′														
50	Virginia	37	55	260	E.&W.	Sandy loam	1903	16	Mar. 28	Apr. 2		Apr. 5		July –		July 5	Aug.
50	do	37	55	200	E.&W.	do	1904	17	Apr. 20	Apr. 25	Apr. 6	Apr. 25		July 10	Sept. 7		
50	do	37	55	200	E.&W.	do	1905	18	Apr. 10	Apr. 14	Apr. 19	Apr. 14		July 5	Oct. 22	July 5	Aug.
50	do	37	55	200	E.&W.	do	1906	19	Apr. 15	Apr. 25	May 11	Apr. 25		July 10			Do.
50	do	37	55	200	E.&W.	do	1907	20			May –[a]						
20	do	38	0	700	S.	Clay loam	1905	30	Apr. 10	Apr. 14	Apr. 18	Mar. 29					
36	do	38	15	650		Sandy loam	1902	11	Apr. 18	Apr. 20	May 3	Apr. 18			Oct. 17		
35	do	38	30	400	NE.	Red clay	1902	2	Apr. 20	Apr. 24	Apr. 15	Mar. 29	Aug. 25		Oct. 22		
35	do	38	30	400	NE.	do	1903	3	Mar. 30	Apr. 5	Apr. 5	Mar. 20	Aug. 3	July 9	Oct. 18		July.
35	do	38	30	400	NE.	do	1904	4	Apr. 26	May 4	Apr. 23	Apr. 3	July 3		Sept. 23		
35	do	38	30	400	NE.	do	1905	5	Apr. 10	Apr. 18	Apr. 20	Mar. 31	July 11	July 8	Sept. 13		July.
35	do	38	30	400	NE.	do	1906	6	Apr. 19	Apr. 23	May 10	Apr. 8	July 14		Oct. 12		
78	Delaware	38	45	50	SE.	Sandy loam	1904	21	Apr. 25	May 4	Apr. 22	Apr. 3					
34	Virginia	38	45	300	W.	Clay loam	1902	13	Apr. 15		May 30[b]				Sept. 18		
48	do	38	45	375	SE.	Sandy loam	1903	15	Apr. 8	Apr. 11	Apr. 5	Apr. 15	June 28	July 10	Oct. 25		July.
48	do	38	45	375	SE.	do	1905	20	Apr. 21	Apr. 24	Apr. 19[b]	Apr. 21					
56	do	38	50	950	NW.	Clay loam	1907	4	Apr. 10	Apr. 20	Apr. 10	Apr. 15		July 1		July 1	
54	do	39	0	1,000	NE.	Sandy loam	1902	18	Apr. 23	Apr. 28	Apr. 14	Apr. 14	June 15	do		do	July.
54	do	39	0	1,000	NE.	do	1903	19	Apr. 9	Apr. 20	Apr. 5	Mar. 27	June 10	July 4		July 10	Do.
54	do	39	0	1,000	NE.	do	1904	20	May 1	May 6	Apr. 20	Apr. 19	do				
54	do	39	0	1,000	NE.	do	1905	21	Apr. 13	Apr. 22	Apr. 19	Apr. 4	do				
54	do	39	0	1,000	NE.	do	1906	22	Apr. 20	Apr. 27	May 8	Apr. 16	do	July 1		July 1	Aug.
54	do	39	0	1,000	NE.	do	1907	23	Apr. 16	Apr. 24	Apr. 23	Mar. 29	do	do		do	Do.
75	Delaware	39	0	60	None.	do	1906	20	Apr. 21	Apr. 27	Apr. 3	Apr. 18			Oct. 12		
72	do	39	10	70	None.	do	1902	25	Apr. 24	do				July 1	Oct. 20	July 1	
74	do	39	10	80	None.	Clay loam	1903	8	Apr. 16	Apr. 24	Apr. 6			July 10	Oct. 22	July 10	
67	Maryland	39	20	50	E.	Sandy loam	1903	30	Apr. 9	Apr. 13	do	Apr. 6		July 1	Oct. 26	July 15	
65	do	39	20	75		do	1902	7	Apr. 23	Apr. 27		Apr. 8		July 15	Nov. –	do	
65	do	39	20	75		do	1903	8	Apr. 9	Apr. 20		Mar. 26					
63	do	39	30	150	N.	Clay loam	1907	20	Apr. 29	May 6	May 12	Apr. 19	July 28	July 15	Oct. 15	July 10	July.
60	do	39	35	75	SW.	Heavy loam	1902	25	do	May 2	May 28	Apr. 25	July 5	July 8	Nov. 15	July 8	Do.
60	do	39	35	75	SW.	do	1903	26	Apr. 16	Apr. 23	Apr. 20	Apr. 4			Nov. –		
60	do	39	35	75	SW.	do	1904	27	May 7	May 10	May 11	Apr. 30	June 29	July 25	Sept. 17		July.
60a	do	39	35	125	SW.	Sandy loam	1902	29	Apr. 28	May 1	Apr. 20	Apr. 22		July 15	Nov. 15	July 10	Do.
60a	do	39	35	125	SW.	do	1903	30	Apr. 16	Apr. 23	do	Apr. 4	July 4		Nov. –		
60a	do	39	35	125	SW.	do	1904	31	May 2	May 8	Apr. 21	Apr. 26	June 25	July 25	Sept. 17		Aug.
79	New Jersey	39	35	90	NW.	Gravelly loam	1902	50	Apr. 21	Apr. 27	Apr. 15	Apr. 19		July 6	Oct. 22	July 6	July.
59	Maryland	39	40	300	None.	do	1902	15	Apr. 26	Apr. 28	do	Apr. 15	July 1	July 10		July 4	Do.
82	New Jersey	39	55	50	W.	Sandy loam	1902	20	Apr. 21	Apr. 27				July 11		July 11	Do.
84	do	39	55	50	N.	do	1902	35	Apr. 25	Apr. 30	Apr. 16	Apr. 20	Aug. 1	July 10	Oct. 10	July 20	

84	do	39	55	50	N.	do	1903	36	Apr. 18	Apr. 25	May 2	Apr. 1	July 25	July 15	Oct. –	July 15	
84	do	39	55	50	N.	do	1904	37	May 3	May 8		Apr. 25	do	July 1		July 1	
80	do	40	5	50	N.	Gravelly loam	1904	40	May 5	do	Apr. 24		June 1	July 20	Oct. 10	July 4	
97	do	40	5	60	SW.	Sandy loam	1905	35	Apr. 14							July 20	
94	do	40	20	150	S.	do	1902	38	Apr. 23	Apr. 27	Apr. 28	Apr. 20	June 27	July 8		July 8	July.
94	do	40	20	150	S.	do	1905	41	Apr. 29	May 4	Apr. 19	Apr. 10		July 10	Oct. –	July 10	Do.
94	do	40	20	150	S.	do	1906	42	Apr. 30	May 5		Apr. 18	June 5	do	Oct. 14	do	Do.
94	do	40	20	150	S.	do	1907	43	May 10	May 13		Apr. 24	July 5	July 15	Oct. 20	July 20	Do.
98	do	40	30	600	S.	Red shale	1905	14	May 1	May 6					Oct. –		
88	do	40	50	500	E.	Sandy loam	1907	18	May 8	May 12	Apr. 25	Apr. 14		July 25	Oct. 10	July 25	July.
101	do	41	10	550	SE.	Gravelly	1904	15	May 6	May 17	Apr. 23	Apr. 28			Sept. 22		
103	do	41	15	400	SW.	Sandy loam	1904		May 10	May 15	May 5				Sept. 28		

EARLY RIPE.

6	North Carolina	35	5	200	None.	Sandy	1904		Mar. 18	Mar. 24							
3	do	35	25	770	N.	do	1905	8	Apr. 2	Apr. 9	Apr. 18	Mar. 20	May 22	June 10	Oct. 22	June 10	
13	do	35	25	2,180	NE.	Porous clay	1904	15	Apr. 22	May 10	Apr. 17	Apr. 25	May 30	June 25	Oct. 15	June 25	
38	Virginia	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 20	Apr. 29	Apr. 18	Apr. 5			Sept. 14		
38	do	37	15	2,170	NW.	do	1903	14	Apr. 8	Apr. 20	Apr. 5	Mar. 25			do		
38	do	37	15	2,170	NW.	do	1904	15	May 1	May 7	May 16	Apr. 19	June 20		Oct. 15		
35	do	38	30	400	NE.	Red clay	1902	15	Apr. 21	Apr. 25	Apr. 15	Mar. 29	Aug. 25	July 9	Sept. 22	June 29	July.
35	do	38	30	400	NE.	do	1903	16	Mar. 30	Apr. 5	Apr. 5	Mar. 20	Aug. 3	July 7	Sept. 18	June 15	Do.
35	do	38	30	400	NE.	do	1904	17	Apr. 24	May 1	Apr. 23	Apr. 2	July 15	July 25	Sept. 23	June 28	Do.
35	do	38	30	400	NE.	do	1905	18	Apr. 11	Apr. 17	Apr. 20	Mar. 31	July 12	July 12	Oct. 13	June 19	Do.
35	do	38	30	400	NE.	do	1906	19	Apr. 18	Apr. 22	May 10	Apr. 8	July 18	July 14	Oct. 12	July 4	Do.
76	Delaware	39	5	40	NE.	Sandy	1903	10	Apr. 4	Apr. 8	Apr. 6	Mar. 28	June 1	June 18			
76	do	39	5	40	NE.	do	1904	11	Apr. 27	Apr. 30	Apr. 21	Apr. 20	do	July 1	Oct. 28		
76	do	39	5	40	NE.	do	1905	12	Apr. 18	Apr. 21	Apr. 19	Mar. 30	June 2	June 30	Oct. 22		
65	Maryland	39	20	75		Gravelly loam	1902	7	Apr. 23	Apr. 27		Apr. 1		July 5	Nov. –		
65	do	39	20	75		do	1903	8	Apr. 9	Apr. 20		do					
94	New Jersey	40	20	150	S.	Sandy loam	1903	30	Apr. 22	Apr. 27	May 5	Apr. 9	June 13	July 11	Oct. –		July.

FALL PIPPIN.

10c	North Carolina	35	30	4,000	NE.	Clay loam	1902	6	May 2	May 6	Apr. 25	May 8	July 26	Oct. 15	Oct. 3	Nov. 1	Dec.
33	Virginia	37	0	5	None.	Sandy loam	1904	8	Apr. 23	Apr. 28	Apr. 20	Apr. 3	June 23	Sept. 1	Oct. 17		
38	do	37	15	2,170	NW.	Limestone clay	1903	12	Apr. 15	do	Apr. 5	Apr. 28		Sept. 14			
38	do	37	15	2,170	NW.	do	1904	13	May 6	May 11	May 16	Apr. 22	June 29	Oct. 15			
72	Delaware	39	10	70	None.	Sandy loam	1902	10	Apr. 22	Apr. 25				Sept. 15	Oct. 20	Sept. 15	Dec.
87	New Jersey	39	15	40	SW.	do	1902	10	Apr. 30	May 7		Apr. 24					
93	do	40	15	200	SE.	do	1907	43	May 8	May 11	May 30	May 1		Sept. 6	Nov. –	Oct. –	Nov.
100	do	40	35	600	N.	Clay loam	1903	24	Apr. 24			Apr. 1					
100	do	40	35	600	N.	do	1904	25	May 10	May 16	Apr. 22	May 3					
103	do	41	15	400	SW.	Sandy loam	1904		May –	May 14	May 5				Sept. 28		

a Frost killed the entire crop.

b Frost seriously injured crop.

TABLE IV.—*Phenological records—Apples*—Continued.

FAMEUSE.

Observer number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
		° ′														
38	Virginia	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 25	May 2	Apr. 18	Apr. 11			Sept. 14		
38	do	37 15	2,170	NW.	do	1903	14	Apr. 15	Apr. 21	Apr. 15	Apr. 6		Sept. 20	do		
38	do	37 15	2,170	NW.	do	1904	15	May 6	May 10	May 16	Apr. 17	June 25		Oct. 15		
72	Delaware	39 10	70	None.	Sandy loam	1902	30	Apr. 25	Apr. 28				Aug. 15	Oct. 20		
60	Maryland	39 35	75	SW.	Heavy loam	1902	25	Apr. 30	May 2	May 28	Apr. 23	July 5		Nov. 15		
60	do	39 35	75	SW.	do	1903	26	Apr. 28	do	Apr. 20	Apr. 2			Nov. –		
60	do	39 35	75	SW.	do	1904	27	May 4	May 9	May 11	May 1	June 30	Oct. 5	Sept. 11		
94	New Jersey	40 20	150	S.	Sandy loam	1902	38			Apr. 28	Apr. 20		Sept. 20	Oct. 10	Sept. 20	Oct.
94	do	40 20	150	S.	do	1904	40	May 8	May 11		Apr. 30	July 16	Sept. 1	Sept. 20	Sept. 10	Do.
94	do	40 20	150	S.	do	1905	41	Apr. 30	May 5	Apr. 19			do	Oct. –	Sept. 1	Do.
94	do	40 20	150	S.	do	1906	42	May 3	May 9	May 11	Apr. 18	June 5		Oct. 14		
94	do	40 20	150	S.	do	1907	43	May 10	May 13		Apr. 26	July 3	Sept. 17	Oct. 20	Oct. 1	Oct.
103	do	41 15	400	SW.	do	1904			May 14	May 5				Sept. 28		

FANNY.

Observer number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
38	Virginia	37 15	2,170	NW.	Limestone clay	1903	14	Apr. 14	Apr. 26	Apr. 5	Apr. 5		Sept. 15	Sept. 14	Oct.	
38	do	37 15	2,170	NW.	do	1904	15			May 16	Apr. 18	June 17		Oct. 15		
72	Delaware	39 10	70	None.	Sandy loam	1902	10	Apr. 23	Apr. 26				Aug. 1	Oct. 20		

GANO.

Observer number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
38	Virginia	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 26	May 2	Apr. 18	Apr. 12		Sept. 25	Sept. 14		
38	do	37 15	2,170	NW.	do	1903	14	Apr. 12	Apr. 27	Apr. 5	Apr. 7		Oct. 1	do		Mar.
38	do	37 15	2,170	NW.	do	1904	15	May 7	May 12	May 16	Apr. 20	June 24		Oct. 15		
53	do	38 25	1,400	W.	Gravelly	1902	4	Apr. 25	May 1		Apr. 10		Oct. 1		Nov. –	Feb.
53	do	38 25	1,400	W.	do	1903	5	Apr. 12	Apr. 22		Apr. 9		Oct. –		do	Do.
53	do	38 25	1,400	W.	do	1905	7	Apr. 15	Apr. 25	Apr. 24	Apr. 6		do	Oct. –		Do.
53	do	38 25	1,400	W.	do	1906	8	Apr. 25	May 1	May 11	Apr. 15		Sept. –	Oct. 8	Sept. –	Jan.

GRAVENSTEIN.

33	Virginia	37	0	5	None.	Sandy loam	1904	8	Apr. 13	Apr. 26	Apr. 20	Apr. 1	June 26	Aug. 1	Oct. 17	Aug. 1	Aug.
38	...do	37	15	2,170	NW.	Limestone clay	1903	14	...do	Apr. 28	Apr. 5	Mar. 25	...	...	Sept. 14	...	...
38	...do	37	15	2,170	NW.	...do	1904	15	May 2	May 8	May 16	Apr. 20	June 26	...	Oct. 15	...	...
35	...do	38	30	400	NE.	Red clay	1902	15	Apr. 25	Apr. 26	Apr. 15	Apr. 13	Aug. 27	...	Oct. 22	...	...
35	...do	38	30	400	NE.	...do	1903	16	...	...	Apr. 5	...	...	...	Oct. 18	...	...
35	...do	38	30	400	NE.	...do	1904	17	Apr. 29	May 4	Apr. 23	Apr. 10	July 14	...	Sept. 23	...	...
35	...do	38	30	400	NE.	...do	1905	5	...	...	Apr. 20	Apr. 2	July 22	...	Oct. 13	...	...
54	...do	39	0	1,000	NE.	Porous loam	1902	8	Apr. 23	Apr. 26	Apr. 14	Apr. 15	June 10	Sept. 1	...	Sept. 15	Oct.
72	Delaware	39	10	70	None.	Sandy loam	1902	10	...do	...do	...	...	...	Aug. 1	Oct. 20	Aug. 5	Aug.
84	New Jersey	39	55	50	N.	Heavy loam	1902	25	Apr. 22	Apr. 29	Apr. 16	Apr. 10	Aug. 15	July 25	Oct. 10	Aug. 1	Do.
84	...do	39	55	50	N.	...do	1903	26	Apr. 18	Apr. 26	May 2	Apr. 1	Aug. 1	Aug. 25	Oct. –	July 25	Sept.
84	...do	39	55	50	N.	...do	1904	27	May 5	May 9	...	Apr. 25	July 25	Aug. 1	...	Aug. 10	Aug.
86	...do	40	0	50	NW.	Loam	1904	20	May 3	May 5	...	...do	July 10	...do	...	...	...
86	...do	40	0	50	NW.	...do	1905	21	May 1	May 6	...	May 8	July 1	...do	Sept. 22	Aug. –	Sept.
89	...do	40	5	50	N.	Gravelly loam	1904	35	May 4	May 7	Apr. 24	...	June 1	Aug. 25	Oct. 10	Aug. 10	Do.
89	...do	40	5	50	N.	...do	1905	50	Apr. 24	May 2	Apr. 19	Apr. 18	June 7	Sept. 1	Oct. 15	Aug. 20	Nov.
89	...do	40	5	50	N.	...do	1906	37	Apr. 23	Apr. 28	Apr. 6	...	...do	Aug. 25	...	Aug. 5	Sept.
89	...do	40	5	50	N.	...do	1907	50	Apr. 28	May 6	Apr. 20	Apr. 6	June 20	...do	...	...	...
96	...do	40	15	90	N. & S.	Clay loam	1904	25	May 7	May 12	...	May 4	...	Aug. 1	Sept. 17	Aug. 10	...
96	...do	40	15	90	N. & S.	...do	1905	26	Apr. 29	May 4	Apr. –	Apr. 15	...	Aug. 15	Oct. 18	Aug. 15	...
96	...do	40	15	90	N. & S.	...do	1906	27	Apr. 30	May 2	Apr. 18	Apr. 20	...	July 23	...do	July –	Sept.
92	...do	40	15	200	SE.	...do	1906	35	Apr. 23	Apr. 29	May 10	...	...	...	Oct. –	Aug. –	...
92	...do	40	15	200	SE.	...do	1907	36	May 5	May 11	May 22	Apr. 29	June 20	Sept. 1	...do	Sept. –	...
94	...do	40	20	150	S.	Sandy loam	1903	37	Apr. 25	Apr. 30	May 5	Apr. 9	June 13	Aug. 18	...do	Aug. –	Aug.
100	...do	40	35	600	N.	Clay loam	1903	16	Apr. 26	Apr. 28	...	...	...	...	...	...	...
100	...do	40	35	600	N.	...do	1904	17	May 8	May 14	Apr. 22	May 1	...	...	...	...	...

GRIMES. Synonym: *Grimes Golden.*

12	North Carolina	35	25	2,128	W.	Porous loam	1902	20	Apr. 24	May 1	Apr. 5	Apr. 22	July 8	Sept. 20	Oct. 15	Oct. 1	Jan.
30	Virginia	37	10	2,000	NW.	Dark loam	1902	10	Apr. 26	...do	May 18	Apr. 20	...	Oct. 10	Sept. 10	...	Dec.
38	...do	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 27	May 4	Apr. 18	Apr. 12	...	Sept. 15	Sept. 14	...	...
38	...do	37	15	2,170	NW.	...do	1903	14	Apr. 13	Apr. 26	Apr. 5	Apr. 6	...	...	...do	Sept. 20	Oct.
38	...do	37	15	2,170	NW.	...do	1904	15	May 7	May 12	May 16	Apr. 20	June 24	...	Oct. 15	...	...
51	...do	37	25	1,400	NW.	Gravelly loam	1902	12	Apr. 20	Apr. 23	Apr. 8	Apr. 21	July –	Sept. 15	...	Sept. 15	Dec.
53	...do	38	25	1,400	W.	...do	1903	11	Apr. 11	Apr. 21	...	Apr. 9	...	Sept. –	...	Nov. –	Do.
53	...do	38	25	1,400	W.	...do	1905	19	Apr. 18	Apr. 28	Apr. 24	Apr. 6	...	...do	Oct. –	Oct. –	Do.
53	...do	38	25	1,400	W.	...do	1906	20	Apr. 25	May 1	May 11	Apr. 15	...	Sept. 25	...	...do	Do.
48	...do	38	45	375	SE.	Porous loam	1903	10	Apr. 8	Apr. 11	Apr. 5	Apr. 16	July 1	Sept. 1	Oct. 25	...	Do.
48	...do	38	45	375	SE.	...do	1906	15	Apr. 27	Apr. 29	May 11	May 1	...	...	Oct. 11	Aug. 15	Oct.
48	...do	38	45	375	SE.	...do	1907	16	Apr. 29	May 1	Apr. 29	...	...	Sept. 20	Oct. 13	...	Dec.
54	...do	39	0	1,000	NE.	...do	1902	9	Apr. 24	Apr. 29	Apr. 14	Apr. 15	June 15	Sept. 10	...	Sept. 15	Do.
54	...do	39	0	1,000	NE.	...do	1903	10	Apr. 6	Apr. 20	Apr. 5	Mar. 31	June 10	...do	...	Sept. 20	Do.
54	...do	39	0	1,000	NE.	...do	1904	16	May 4	May 8	Apr. 20	Apr. 25	...do	...	...	...	...
54	...do	39	0	1,000	NE.	...do	1905	17	Apr. 19	Apr. 26	Apr. 19	Apr. 7	...do	Sept. 25	...	...	...

TABLE IV.—*Phenological records—Apples*—Continued.

GRIMES—Continued.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
		°	′														
54	Virginia	39	0	1,000	NE.	Porous loam	1906	10	Apr. 23	Apr. 28	May 8	Apr. 19	June 10	Sept. 15	....	Oct. 1	Mar.
54	....do	39	0	1,000	NE.	....do	1907	19	Apr. 20	Apr. 25	Apr. 23	Mar. 31	...do	...do	....	...do	Jan.
72	Delaware	39	10	70	None.	Sandy loam	1902	10	Apr. 22	Apr. 26	....	....	....	Sept. 5	Oct. 20	Sept. 15	Dec.
37	Virginia	39	10	600	NW.	Clay loam	1903	......	Apr. 16	Apr. 21	....	....	....	....	....	....	....
68	Maryland	39	10	550	S.	....do	1906	9	Apr. 20	May 1	May 10	Apr. 17	....	Sept. 15	Oct. 12	....	....
64	....do	39	25	225	SE.	Stony loam	1905	20	Apr. 28	....	Apr. 19	Apr. 25	Aug. 20	Sept. 1	Oct. 19	Aug. 15	Nov.
64	....do	39	25	225	SE.	....do	1906	15	Apr. 29	May 3	May 10	May 2	...do	....	Oct. 11	....	....
64	....do	39	25	225	SE.	....do	1907	25	Apr. 28	May 6	May 5	Apr. 28	....	....	Oct. 17	....	....
82	New Jersey	39	55	50	W.	Sandy loam	1902	6	Apr. 25	May 2	....	....	....	Sept. 1	....	Sept. 1	Oct.
84	....do	39	55	50	N.	Heavy loam	1902	10	Apr. 27	May 1	Apr. 16	Apr. 20	Sept. 10	Sept. 25	Oct. 10	Oct. 1	Do.

JERSEY SWEET.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
33	Virginia	37	0	5	SW.	Sandy loam	1904	8	Apr. 18	Apr. 29	Apr. 20	Apr. 1	June 26	Aug. 4	Oct. 17	Aug. 4	Aug. 10.
38	....do	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 2	Apr. 8	Apr. 10	....	....	Sept. 14	....	....
38	....do	37	15	2,170	NW.	....do	1903	14	Apr. 14	Apr. 26	Apr. 5	Mar. 29	....	....	...do	....	....
38	....do	37	15	2,170	NW.	....do	1904	15	May 1	May 12	May 16	Apr. 17	June 26	....	Oct. 15	....	....
94	New Jersey	40	20	140	SW.	Sandy loam	1905	41	Apr. 30	May 5	Apr. 19	....	....	Aug. 10	....	Aug. 10	Aug.

JONATHAN.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
47	Virginia	36	45	1,700	SE.	Porous loam	1905	......	Apr. 15	May 1	May 1	....	....	Sept. 15	....	Oct. 1	Dec.
72	Delaware	39	10	70	None.	Sandy loam	1902	7	Apr. 25	Apr. 28	....	....	....	...do	Oct. 20	Sept. 15	Do.
82	New Jersey	39	55	50	W.	....do	1902	6	Apr. 24	Apr. 29	....	....	....	Sept. 25	....	Sept. 20	Do.
82	....do	39	55	50	W.	....do	1903	7	Apr. 16	....	....	....	....	....	....	....	....
99	....do	40	35	40	NW.	....do	1907	10	May 9	May 13	May 12	May 1	Sept. 15	Oct. 15	....	Oct. –	Apr.

JULY.

76	Delaware	39	5	40	None.	Sandy	1903	8	Apr. 11	Apr. 16	Apr. 6	Apr. 1	June 1	July 8			July.
76	do	39	5	40	None.	do	1905	10	Apr. 20	Apr. 24	Apr. 19	do	June 7	July 12	Oct. 22		
72	do	39	10	70	None.	Sandy loam	1902	10	Apr. 24	Apr. 27				July 10	Oct. 20		
65	Maryland	39	20	75		Gravelly loam	1902	5	Apr. 25	Apr. 29		Apr. 12					
65	do	39	20	75		do	1903	6	Apr. 18			Apr. 2					

LIMBERTWIG.

11	North Carolina	35	25	1,990	SE.	Porous loam	1904	20	Apr. 30	May 5	Apr. 21	May 8		Oct. 20	Oct. 24	Dec. –	Mar.
10*b*	do	35	30	3,500	SE.	Gravelly clay	1902	12	Apr. 29	May 7	Apr. 20	May 10	July 28	Oct. 10	Oct. 3	do	Jan.
10*c*	do	35	30	4,000	NE.	Clay loam	1902	8	May 1	May 9	Apr. 25	May 8	do	Oct. 20	do	do	Mar.
10*d*	do	35	30	4,500	SE.	Black loam	1902	12	do	May 6	Apr. 22		July 30	do	Oct. 1	do	Feb.
1	do	35	35	2,300	S.	Loam	1904	12	Apr. 15	Apr. 28	Apr. 20	Apr. 3					
1	do	35	35	2,300	S.	do	1905	13	Apr. 5	Apr. 15	Apr. 16	Mar. 27		Oct. 15	Oct. 15	Jan. –	
1	do	35	35	2,300	S.	do	1906	9	Apr. 20	Apr. 26	Apr. 18	Apr. 15			do		
5	do	35	50	1,500	N.	Black loam	1905	15	Apr. 10	Apr. 18	Mar. 30	Apr. 2	May 5	Nov. 1	Oct. –	Oct. –	May.
5	do	35	50	1,500	N.	do	1906	18	Mar. 30	Apr. 9				do		do	Mar.
4	do	35	50	1,200	S.	Sandy loam	1904	20	Apr. 15	May 1		May 15		do		do	Apr.
16	do	36	10	3,250	S.	Clay loam	1904	16	May 10	May 20	Apr. 21	Apr. 23	July 6	Oct. 15	Oct. 15	Jan. –	May.
16	do	36	10	3,250	S.	do	1905	17	Apr. 25	May 4	May 16	Apr. 16	July 11	do	Oct. 20	do	Do.
47	Virginia	36	45	1,700	SE.	Porous loam	1905		Apr. 20	May 5	May 1			Oct. 25		do	June.
38	do	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 4	Apr. 18	Apr. 11		Sept. 25	Sept. 14		
38	do	37	15	2,170	NW.	do	1903	14	Apr. 17	Apr. 29	Apr. 5	Mar. 30		Oct. 1	do		
38	do	37	15	2,170	NW.	do	1904	15	May 6	May 11	May 16	Apr. 24	June 30		Oct. 15		
44	do	37	45	630	SW.	Loam	1904	15	Apr. 24		Apr. – *a*	Apr. 6	do				
50	do	37	55	200	E.&W.	Sandy loam	1903	16	Mar. 29	Apr. 4		Apr. 5		Oct. –		Oct. –	Mar.
19	do	38	5	900	S.	Red clay	1905	18	Apr. 11	Apr. 15	Apr. 19	Apr. 1		Oct. 25	Oct. 7	Mar. –	May.

LONDON SWEET.

35	Virginia	38	30	400	NE.	Red clay	1902	15	Apr. 24	Apr. 26	Apr. 15	Apr. 16	Aug. 27		Oct. 22		
35	do	38	30	400	NE.	do	1903	16	Apr. 7	Apr. 14	Apr. 5	Mar. 20	Aug. 2	Aug. 22	Oct. 18	Aug. –	Oct.
35	do	38	30	400	NE.	do	1904	17	Apr. 30	May 5	Apr. 23	Apr. 8	Aug. 22	Sept. 1	Sept. 23	do	Do.
35	do	38	30	400	NE.	do	1905	18	Apr. 14	Apr. 22	Apr. 20	Mar. 30	July 16	do	Oct. 13	do	Sept.

a Frost seriously injured crop.

TABLE IV.—*Phenological records—Apples*—Continued.

MAIDEN BLUSH.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
[illegible]	Virginia	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 27	May 3	Apr. 18	Apr. 10	....	....	Sept. 14	....	....
[illegible]	..do..	37 15	2,170	NW.	..do..	1903	14	Apr. 15	Apr. 27	Apr. 15	Apr. 6	....	....	..do..	....	....
[illegible]	..do..	37 15	2,170	NW.	..do..	1904	15	May 8	May 13	May 16	Apr. 22	June 27	....	Oct. 15	....	....
[illegible]	..do..	37 25	1,400	NW.	Gravelly loam	1902	12	Apr. 20	Apr. 24	Apr. 8	Apr. 20	July –	Sept. 25	....	Sept. 1	Dec.
[illegible]	..do..	38 30	400	NE.	Red clay	1902	15	Apr. 24	Apr. 26	Apr. 15	Apr. 13	Aug. 25	Aug. 1	Oct. 22	July 25	Aug.
[illegible]	..do..	38 30	400	NE.	..do..	1903	16	Apr. 7	Apr. 12	Apr. 5	Mar. 20	July 28	Aug. 15	Oct. 18	July 1	Sept.
[illegible]	..do..	38 30	400	NE.	..do..	1904	17	May 2	May 5	Apr. 23	Apr. 9	July 17	....	Sept. 23	....	....
[illegible]	..do..	38 30	400	NE.	..do..	1905	18	Apr. 16	Apr. 24	Apr. 20	Mar. 30	July 14	Aug. 1	Oct. 13	July 10	Sept.
74	..do..	39 10	1,000	NE.	Porous loam	1903	20	Apr. 9	Apr. 20	Apr. 5	Mar. 28	June 10	..do..	....	....	Aug.
74	..do..	39 10	1,000	NE.	..do..	1905	17	Apr. 20	Apr. 25	Apr. 19	Apr. 6	..do..	....	....	....	....
74	..do..	39 10	1,000	NE.	..do..	1907	19	..do..	..do..	Apr. 23	Mar. 31	June 15	Aug. 15	....	Aug. 15	Sept.
[illegible]	..do..	39 10	600	E.	Sandy loam	1907	14	Apr. 24	Apr. 30	May 9	Mar. 27	....	..do..	....	Aug. 25	Do.
72	Delaware	39 10	70	None.	..do..	1903	30	Apr. 22	Apr. 26	....	....	....	Aug. 1	Oct. 20	Aug. 5	Do.
80	New Jersey	39 40	150	None.	Porous loam	1904	25	May 5	May 10	Apr. 17	May 2	June 15	Aug. 5	Sept. 25	..do..	....
82	..do..	39 55	50	W.	Sandy loam	1902	20	Apr. 24	Apr. 28	....	....	....	Aug. 15	....	Aug. 15	Sept.
94	..do..	40 20	150	S.	..do..	1902	38	Apr. 27	May 4	Apr. 28	Apr. 20	June 27	Aug. 10	Oct. 10	Aug. –	Do.
94	..do..	40 20	150	S.	..do..	1903	39	Apr. 28	May 2	May 5	Apr. 9	June 13	Aug. 18	Oct. –	..do..	Aug.
94	..do..	40 20	150	S.	..do..	1904	40	May 7	May 11	....	Apr. 30	July 16	Aug. 25	Sept. 20	Sept. 1	Sept.

MILAM.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
53	Virginia	38 25	1,400	W.	Gravelly loam	1903	9	Apr. 12	Apr. 24	....	Apr. 9	....	Sept. –	....	Nov. –	Feb.
53	..do..	38 25	1,400	W.	..do..	1905	11	Apr. 17	Apr. 25	Apr. 24	Apr. 11	....	..do..	....	Sept. –	Jan.
53	..do..	38 25	1,400	W.	..do..	1906	12	Apr. 27	May 2	May 11	Apr. 13	....	..do..	....	....	....
54	..do..	39 0	1,000	NE.	Porous loam	1902	15	Apr. 24	Apr. 29	May 14	Apr. 17	June 15	Sept. 10	....	Sept. 15	Nov.
54	..do..	39 0	1,000	NE.	..do..	1903	16	Apr. 13	Apr. 22	May 5	Apr. 1	June 10	Sept. 25	....	Oct. 1	Dec.
54	..do..	39 0	1,000	NE.	..do..	1904	17	May 5	May 10	May 20	Apr. 22	..do..	....	....	....	....
54	..do..	39 0	1,000	NE.	..do..	1905	18	Apr. 22	Apr. 25	May 19	Apr. 10	..do..	....	....	....	....

NERO.

38	Virginia	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 26	May 3	Apr. 18	Apr. 10			Sept. 14		
38	do	37	15	2,170	NW.	do	1903	14	Apr. 15	Apr. 20	Apr. 5	Apr. 13		Sept. 25	do.		
38	do	37	15	2,170	NW.	do	1904	15	May 3	May 8	May 16	Apr. 16	June 26		Oct. 15		
76	Delaware	39	5	40	NE.	Sandy loam	1903	19	Apr. 8	Apr. 20	Apr. 6	Mar. 28	June 16	Oct. 5			Jan.
76	do	39	5	40	NE.	do	1904	20	Apr. 27	May 4	Apr. 21	Apr. 23	June 14	Oct. 18	Oct. 28		Feb.
76	do	39	5	40	NE.	do	1905	21	Apr. 19	Apr. 25	Apr. 19	Mar. 28	May 30	Oct. 19	Oct. 22	Nov. 1	Do.
82	New Jersey	39	55	50	W.	do	1902	6	Apr. 24	Apr. 28				Oct. 1		Oct. 1	Dec.
82	do	39	55	50	W.	do	1903	7	Apr. 16								
92	do	40	15	200	SE.	do	1907	20	May 8	May 11	May 30	May 1		Nov. 1	Nov. –	Dec. –	Mar.
94	do	40	20	150	S.	do	1902	38	Apr. 22	Apr. 23	Apr. 28	Apr. 20	June 27	Oct. 10	Oct. 10	Nov –	Dec.
94	do	40	20	150	S.	do	1903	39	Apr. 20	Apr. 26	May –	Apr. 9	June 13	Oct. 1	Oct. –	do.	Feb.
94	do	40	20	150	S.	do	1905	41	Apr. 27	May 1	Apr. 19			Oct. –	do.	Oct. –	Nov.

NORTHERN SPY.

4	North Carolina	35	50	1,200	S.	Sandy loam	1904	20	Apr. 15	May 1		May 15					
38	Virginia	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 30	May 5	Apr. 18	Apr. 11			Sept. 14		
38	do	37	15	2,170	NW.	do	1903	14	do.	May 12	Apr. 5	Apr. 16		Sept. 20	do.	Oct. 1	Dec.
38	do	37	15	2,170	NW.	do	1904	15	May 9	May 14	May 16	Apr. 28	June 24		Oct. 15		
29	do	37	20	1,200	SE.	Red clay	1903	20	Apr. 10	Apr. 18	Apr. 6	Apr. 20		Aug. –		Sept. –	Dec.
28	do	37	20	1,000	None.	Sandy loam	1904	15	Apr. 15	Apr. 25	May 7			Oct. 20		Oct. –	Late.
28	do	37	20	1,000	None.	do	1905	10	Apr. 9	Apr. 16	Mar. 28	Apr. 1	June 10		Oct. 13		
28	do	37	20	1,000	None.	do	1906	20	Apr. 12	Apr. 19	Mar. 29	Apr. 2			Nov. 20		
54	do	39	0	1,000	NE.	Porous loam	1902	8	Apr. 26	Apr. 30	Apr. 14	Apr. 22	June 15	Sept. 20		Oct. 1	
54	do	39	0	1,000	NE.	do	1903	9	Apr. 18	Apr. 27	Apr. 5	Apr. 6	June 10	Sept. 25		do.	
54	do	39	0	1,000	NE.	do	1904	10	May 6	May 11	Apr. 20	May 2	do.				Dec.
54	do	39	0	1,000	NE.	do	1905	11	Apr. 24	Apr. 29	Apr. 19	Apr. 11	do.	Sept. 20			
54	do	39	0	1,000	NE.	do	1906	18	Apr. 28	May 2	May 8	Apr. 20	do.	Oct. 1		Oct. 1	Mar.
54	do	39	0	1,000	NE.	do	1907	19	Apr. 29	May 4	Apr. 23	Apr. 4	June 15	do.		Dec. –	Do.
73	Delaware	39	10	100		Sandy loam	1902	20	Apr. 28	do.		Apr. 10		do.		Oct. 15	Dec.
60	Maryland	39	35	75	SSW.	Heavy loam	1902	25	May 1	do.	May 28	Apr. 28	July 12	Sept. 16	Nov. 15	Aug. 12	Feb.
60	do	39	35	75	SSW.	do	1903	26	Apr. 28	May 2	Apr. 20	Apr. 6			Nov. –		
60a	do	39	35	125	SSW.	Sandy loam	1902	35	Apr. 29	do	do	Apr. 25	July 10	Sept. 16	Nov. 15	Aug. 10	Feb.
60a	do	39	35	125	SSW.	do	1903	36	Apr. 20	Apr. 26	do.	Apr. 4		Sept. 20	Nov. –		
60a	do	39	35	125	SSW.	do	1904	37	May 4	May 13	Apr. 21	May 1	July 3	Oct. 3	Sept. 17		
96	New Jersey	40	15	90	N. & S.	Clay loam	1903	19	Apr. 25			May 7					
96	do	40	15	90	N. & S.	do	1904	20	May 8	May 18	Apr. 22	May 5					
92	do	40	15	200	SE.	do	1906	35	Apr. 26	May 3	May 10			Oct. 15	Oct. –	Oct. 15	Jan.
92	do	40	15	200	SE.	do	1907	36	May 11	May 15	May 22	May 5	June 10	Oct. 1	do.	Dec. 25	Do.
94	do	40	20	150	S.	Sandy loam	1904	40				May 1	July 16	Aug. –		Aug. 10	Sept.
94	do	40	20	150	S.	do	1905	41	May 4	May 7	Apr. 19			Sept. –	Oct. –	Sept. –	Oct.
94	do	40	20	150	S.	do	1906	42	May 5	May 10	May –	Apr. 22	June 5	Sept. –	do.	do.	
94	do	40	20	150	S.	do	1907	43	May 16	May 20		May 23	July 4	Sept. 20	Oct. 20	Oct. –	Oct.
98	do	40	30	600	S.	Red shale	1905	14	May 3	May 12	Apr. 16	May 6			Oct. –		
104	do	41	0	600	None.	Clay loam	1904	12	May 13		Apr. 23	May 8	July 6	Oct. 18	Sept. 22	Nov. –	Jan.
104	do	41	0	600	None.	do	1905	14	May 8	May 17	Apr. 24	May 28	July 8	Oct. 10	Oct. 22	do.	Mar.

TABLE IV. *Phenological records—Apples*—Continued.

NORTHERN SPY—Continued.

Observer's number.	State.	Approximate latitude. °	′	Elevation (feet).	Slope	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
104	New Jersey	41	0	600	None.	Clay loam	1906	15	May 12	do.	May 11	Apr. 30	July 2	Oct. 12	Oct. 12	Nov. -	Jan.
104	do.	41	0	600	None.	do.	1907	16	May 17	May 22	May 12	May 1	July 5	Oct. 24	Oct. 25	do.	Mar.
102	do.	41	10	800	None.	Sandy loam	1904	23	May 13	May 19							
102	do.	41	10	800	None.	do.	1905	24	May 9		Apr. 26					Dec. -	Apr.
103	do.	41	15	400	SW.	do.	1904		May 12	May 16	May 5				Sept. 28		

OLDENBURG.

Observer's number.	State.	Approximate latitude. °	′	Elevation (feet).	Slope	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
33	Virginia	37	0	5	None.	Sandy loam	1903	7			Apr. 5	Mar. 24		July 22	Oct. 27	July 25	July 30.
33	do.	37	0	5	None.	do.	1904	8	Apr. 12	Apr. 24	Apr. 20	Apr. 1	June 23	July 18	Oct. 17	July 20	July 28.
38	do.	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 26	May 2	Apr. 18	Apr. 11			Sept. 14		
38	do.	37	15	2,170	NW.	do.	1903	14	Apr. 20	Apr. 28	Apr. 5	Mar. 27			do.		
38	do.	37	15	2,170	NW.	do.	1905	15	Apr. 29	May 7	May 16	Apr. 21	June 22		Oct. 15		
31	do.	37	25	1,400	NW.	Gravelly loam	1902	12	Apr. 21	Apr. 24	Apr. 8	do.	July -	July 1		July 1	Aug. -.
35	do.	38	30	400	NE.	Red clay	1902	3			Apr. 15	Apr. 12	Aug. 26		Oct. 22		
35	do.	38	30	400	NE.	do.	1903	4	Apr. 8	Apr. 13	Apr. 5	Mar. 29	Aug. 3		Oct. 18		
35	do.	38	30	400	NE.	do.	1904	5	Apr. 29	May 5	Apr. 23	Apr. 10	July 17	Aug. 1	Sept. 23	July 25	Aug. 15.
35	do.	38	30	400	NE.	do.	1905	6	Apr. 17	Apr. 23	Apr. 20	Apr. 3	July 24		Oct. 13	July 7	Aug. 19
35	do.	38	30	400	NE.	do.	1906	7	Apr. 19	Apr. 25	May 10	Apr. 15	July 22	Aug. 9	Oct. 11	Aug. 1	Sept. 10
48	do.	38	45	375	SE.	Porous loam	1905		Apr. 21	Apr. 23	Apr. 19						
57	Maryland	39	0	75	None.	Sandy	1907		Apr. 22	May 2	Apr. 18	Mar. 25					
87	New Jersey	39	15	40	SW.	Sandy loam	1902	10	Apr. 28	May 5		Apr. 22					
63	Maryland	39	30	150	N.	Clay loam	1907	20	Apr. 29	May 8	May 12	Apr. 18	July 29	Aug. 10	Oct. 15	Aug. 1	Aug. 20.
84	New Jersey	39	55	50	N.	Heavy loam	1902	25	Apr. 25	Apr. 30	Apr. 16	Apr. 20	Aug. 1	July 25	Oct. 10	July 25	Aug. 10.
84	do.	39	55	50	N.	do.	1903	26	Apr. 18	Apr. 27	May 2	Apr. 5	July 25	July 30	Oct. -	July 30	Do.
84	do.	39	55	50	N.	do.	1904	27	May 1	May 6		Apr. 27	July 10	July 15		July 25	Aug. 1
86	do.	40	0	50	NW.	Loam	1904	20	do.	May 5		Apr. 25	do.	July 10	Sept. 22	July 10	Do.
86	do.	40	0	50	NW.	do.	1905	21	Apr. 27	May 2		Apr. 1	July 1		Nov. -	July 15	Do.
81	do.	40	10	75	None.	Heavy loam	1907	12	May 2	May 10		Apr. 28			Oct. 21		
94	do.	40	20	150	SW.	Sandy loam	1904	14	May 8	May 11		do.	July 16		Sept. 20		
94	do.	40	20	150	SW.	do.	1905	15	May 1	May 5	Apr. 19						
104	do.	41	0	350	None.	Clay loam	1904	12	May 9	May 13	Apr. 23	May 2	July 1	Sept. 8	Sept. 22	Sept. 20	Oct.
104	do.	41	0	350	None.	do.	1905	16	May 6	May 10	Apr. 24	Apr. 26	do.	Aug. 18	Oct. 22	Aug. 18	
104	do.	41	0	350	None.	do.	1906	12	May 5	May 11	May 11	Apr. 20	June 26	Aug. 21	Oct. 12	Aug. 30	
104	do.	41	0	350	None.	do.	1907	13	May 13	May 18	May 12	Apr. 27	July 28	Aug. 19	Oct. 25	Aug. 19	
103	do.	41	15	400	SW.	Sandy loam	1904		May 8	May 13	May 5				Sept. 28		

PRIMATE.

94	New Jersey	40	20	140	S.	Sandy loam	1902	38	Apr. 23	Apr. 27	Apr. 28	Apr. 20	June 27	July 8	Oct. 10	July 8	Aug. 1.
94	do	40	20	140	S.	do	1903	39	Apr. 20	...do...	May –	Apr. 9	June 13	...do...	Oct. –	July 1	July.
94	do	40	20	140	S.	do	1904	40	May 4	May 10		Apr. 20	June 16	July 14	Sept. 20	July 15	July 25.
94	do	40	20	140	S.	do	1905	41	Apr. 30	May 4	Apr. 19			...do...		...do...	Aug. 1.
94	do	40	20	140	S.	do	1906	42	...do...	May 5		Apr. 18	June 5	July 11	Oct. –	July 13	July 20.

RALLS. Synonyms: *Geniton, Rawles Genet, Neverfail.*

47	Virginia	36	45	1,700	SE.	Porous loam	1905		May 10	May 20	May 1					Dec. 1	Apr.
26	do	37	15	900	N.	Sandy loam	1902	15	Apr. 26	May 8							
26	do	37	15	900	N.	do	1903	16	Apr. 19	Apr. 25			June 25	Oct. 10		Nov. 15	Jan.
38	do	37	15	2,170	NW.	Limestone clay	1903	14	May 7	May 12	Apr. 5	Mar. 29			Sept. 14		
38	do	37	15	2,170	NW.	do	1904	15			May 16	May 6	July 15		Oct. 15		
28	do	37	20	1,000	N.	Porous loam	1904	5	May 15	May 25	May 7			Oct. 20			
25	do	37	20	1,000	SE.	Cecil clay	1902	15	May 1	May 10	Mar. 20	May 1	Aug. 1	Oct. 15	Oct. 20	Jan. 1	Mar.
25	do	37	20	1,000	SE.	do	1903	16	May 10	May 20	Apr. 20	May 10	...do...	Nov. 1	Oct. 15	Dec. 1	Feb.
25	do	37	20	1,000	SE.	do	1904	17	May 15	May 25	May 5	May 15	July 20	...do...	Oct. 10	...do...	Do.
25	do	37	20	1,000	SE.	do	1905	18	May 10	May 20	Apr. 15	May 10	...do...	...do...	Oct. 20	...do...	Mar.
27	do	37	30	1,000	NE.	Clay loam	1902	26	May 1	May 4	Mar. –	Apr. 20		Oct. 15	Nov. –	...do...	Feb.
27	do	37	30	1,000	NE.	do	1904	28	...do...	May 3	Apr. 22			Sept. 15	Oct. 16	Nov. –	Do.
42	do	37	45	800	SE.	Cecil clay	1903	15	Apr. 26	May 10	Apr. 15						
36	do	38	15	650		Sandy loam	1902	18	Apr. 24	Apr. 28	May 3	Apr. 24			Oct. 17		
53	do	38	25	1,400	W.	Gravelly loam	1905	19	May 4	May 12	Apr. 24	May 1			Oct. –		
53	do	38	25	1,400	W.	do	1906	20	May 6	May 14	May 11	Apr. 28		Oct. 15	Oct. 8	Dec.	Apr.
35	do	38	30	400	NE.	Red clay	1902	2			Apr. 15	Apr. 22	Aug. 29		Oct. 22		
35	do	38	30	400	NE.	do	1903	3			Apr. 5	Apr. 13	Aug. 4		Oct. 18		
35	do	38	30	400	NE.	do	1904	4	May 7	May 9	Apr. 23	Apr. 29	July 20	Oct. 1	Sept. 23		
35	do	38	30	400	NE.	do	1905	5			Apr. 20	Apr. 14	July 18		Oct. 13		
48	do	38	45	375	SE.	Porous loam	1903	15	Apr. 16	Apr. 22	Apr. 5	Apr. 24	July 8	Sept. 30	Oct. 25		Feb.
48	do	38	45	375	SE.	do	1905	20	Apr. 26	Apr. 28	Apr. 19	Apr. 27					
48	do	38	45	375	SE.	do	1906	60	Apr. 28	Apr. 30	May 11	May 4			Oct. 11	Sept.	Jan.
48	do	38	45	375	SE.	do	1907		May 8	May 11	Apr. 20			Sept. 20	Oct. 13		Do.
54	do	39	0	1,000	NE.	do	1902	19	Apr. 30	May 3	Apr. 14	Apr. 23	June 20	Oct. 1		Nov.	Late.
54	do	39	0	1,000	NE.	do	1903	20	Apr. 27	May 2	Apr. 5	Apr. 29	June 10	Oct. 26		Dec.	June.
54	do	39	0	1,000	NE.	do	1904	21	May 8	May 13	Apr. 20	May 2	...do...				
54	do	39	0	1,000	NE.	do	1905	22	Apr. 26	May 1	Apr. 19	Apr. 17	...do...				
54	do	39	0	1,000	NE.	do	1906	23	May 1	May 5	May 8	Apr. 23	...do...	Oct. 1		Oct.	Apr.
54	do	39	0	1,000	NE.	do	1907		Apr. 30	...do...	Apr. 23	Apr. 4	June 15	...do...		Dec.	June.
55	do	39	0	600	E.	do	1907	14	May 4	May 11	May 9	Apr. 15		Nov. 1	Oct. 10	...do...	Apr.
69	Maryland	39	15	50	None.	Sandy loam	1904	14	Apr. 28	May 14		Apr. 28					
94	New Jersey	40	20	150	S.	do	1905	41	May 4	May 8	Apr. 19	Apr. 20		Oct.	Oct.		June.
94	do	40	20	150	S.	do	1907	43	May 13	May 16		May 28	July 4		Oct. 20		

TABLE IV.—*Phenological records—Apples*—Continued.

RED ASTRACHAN.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
		°	'														
12	North Carolina	35	25	2,128	W.	Porous loam	1902	19	Apr. 18	Apr. 24	Apr. 5	Apr. 16	June 25	July 1	Oct. 15	June 22	July 10.
12	do	35	25	2,128	W.	do	1903	20	Mar. 31	Apr. 7	Apr. 6	Apr. 8					
12	do	35	25	2,128	W.	do	1904	21	Apr. 12	Apr. 20	Apr. 11	Apr. 22	July 26	July 10	Oct. 15	July 12	Aug. 1.
12	do	35	25	2,128	W.	do	1905	22	Apr. 2	Apr. 10	Apr. 7	Apr. 12	July 16	July 15	Oct. 14	July 15	July 25.
1	do	35	35	2,300	S.	Sandy loam	1902	10	Apr. 20	Apr. 26	Apr. 18	do			Oct. 15	June 15	Aug. 1.
1	do	35	35	2,300	S.	do	1904	12	Apr. 12	Apr. 28	Apr. 20	Apr. 3			do		
1	do	35	35	2,300	S.	do	1905	8	Apr. 5	Apr. 15	Apr. 16	Mar. 27			Oct. 16		
1	do	35	35	2,300	S.	do	1906	9	Apr. 20	Apr. 26	Apr. 18	Apr. 12			Oct. 15		
5	do	35	50	1,500	N.	Black loam	1905	18	Mar. 30	Apr. 15	Mar. 30	Mar. 20	May 1	July 15	Oct -	June 30	Aug. 15.
17	do	36	15	3,000	SE.	Clay loam	1904	10	Apr. 25	May 1	May 3	May 1		Aug. 5	Oct. 11	July 25	Sept. 1.
33	Virginia	37	0	5	None.	Sandy loam	1903	7	Mar. 31	Apr. 10	Apr. 5	Mar. 22		July 5	Oct. 27	July 5	July 15.
33	do	37	0	5	None.	do	1904	8	Apr. 12	Apr. 20	Apr. 20	Mar. 27	June 28	July 20	Oct. 17	July 20	July 26.
26	do	37	0	5	None.	do	1902	15	Apr. 19	Apr. 25			June 5	June 18		June 15	July 28.
26	do	37	0	5	None.	do	1903	16	Apr. 1	Apr. 8							
46	do	37	0	500	S.	do	1903	15		Apr. 2		Apr. 1					
38	do	37	0	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 2	Apr. 18	Apr. 11			Sept. 14		
38	do	37	0	2,170	NW.	do	1903	14	Apr. 16	Apr. 20	Apr. 5	Mar. 30			do		
38	do	37	0	2,170	NW.	do	1904	15	May 4	May 10	May 16	Apr. 20	June 20		Oct. 15		
31	do	37	25	1,400	NW.	Gravelly loam	1902	12	Apr. 21	Apr. 24	Apr. 8	Apr. 21	July -	July 1		July 1	Aug.
50	do	37	55	200	E.&W.	Sandy loam	1902	15	Apr. 17	Apr. 23	Apr. 19	May 10		July -	Oct. 30	July -	Aug. 15.
50	do	37	55	200	E.&W.	do	1903	16	Mar. 28	Apr. 2		Apr. 5		do		July 5	Aug. 1.
50	do	37	55	200	E.&W.	do	1904	17	Apr. 20	Apr. 25	Apr. 6	Apr. 25		July 1	Sept. 7		
50	do	37	55	200	E.&W.	do	1905	18	Apr. 9	Apr. 14	Apr. 19	Apr. 14		do	Oct. 22	July 1	Aug. 1.
50	do	37	55	200	E.&W.	do	1906	19	Apr. 15	Apr. 25	May 11	Apr. 25		July 5		July 5	Do.
35	do	38	30	400	NE.	Red clay	1902	3	Apr. 25	Apr. 27	Apr. 15	Apr. 13	Aug. 23		Oct. 22		
35	do	38	30	400	NE.	do	1903	4	Apr. 1	Apr. 9	Apr. 5	Mar. 21	Aug. 1	July 15	Oct. 18		
35	do	38	30	400	NE.	do	1904	5	May 1	May 6	Apr. 23	Apr. 9	July 11		Sept. 23		
35	do	38	30	400	NE.	do	1905	6	Apr. 10	Apr. 18	Apr. 20	Mar. 31	July 13		Oct. 13		
35	do	38	30	400	NE.	do	1906	7	Apr. 19	Apr. 23	May 10	Apr. 10	July 16		Oct. 11		
61	Maryland	38	40	45	None.	Sandy loam	1907	15	Apr. 12	Apr. 29							
48	Virginia	38	45	375	SE.	Porous loam	1903	15	Apr. 5	Apr. 8	Apr. 5	Apr. 15	June 28		Oct. 25		
48	do	38	45	375	SE.	do	1905	20	Apr. 20	Apr. 24	Apr. 19	Apr. 20					
48	do	38	45	375	SE.	do	1906	33	Apr. 24	Apr. 27	May 11	Apr. 30		June 28	Oct. 11	June 24	July 11.
48	do	38	45	375	SE.	do	1907		Apr. 22	Apr. 26	Apr. 20				Oct. 13		Aug. 20.
78	Delaware	38	45	50	None.	Sandy loam	1904	21	Apr. 25	May 4	Apr. 22	Apr. 13					
75	do	39	0	60	None	do	1907	20	Apr. 20	Apr. 26	Apr. 3	Apr. 18		July 9	Oct. -	July 9	
54	Virginia	39	0	1,000	NE.	Porous loam	1902	18	Apr. 22	Apr. 24	Apr. 14	Apr. 15	June 15	June 28		June 28	July 15.

54	do	39	0	1,000	NE.	do	1903	19	Apr. 8	Apr. 18	Apr. 5	Mar. 25	June 10	July 1	....	July 4	Do.
54	do	39	0	1,000	NE.	do	1904	20	May 1	May 6	Apr. 20	Apr. 20	do	....	....	....	....
54	do	39	0	1,000	NE.	do	1905	21	Apr. 14	Apr. 24	Apr. 19	Apr. 5	do	....	....	....	....
54	do	39	0	1,000	NE.	do	1906	22	Apr. 20	Apr. 27	May 8	Apr. 16	do	July 1	....	July 1	Aug.
54	do	39	0	1,000	NE.	do	1907	19	Apr. 17	Apr. 24	Apr. 23	Mar. 31	June 15	do	....	do	Aug. 15.
76	Delaware	39	5	40	None.	Sandy	1903	15	Apr. 3	Apr. 18	Apr. 6	Mar. 28	June 28	June 29	....	....	....
76	do	39	5	40	None.	do	1904	16	Apr. 29	Apr. 30	Apr. 21	Apr. 16	June 14	July 11	Oct. 28	July 11	July 23.
76	do	39	5	40	None.	do	1905	17	Apr. 19	Apr. 21	Apr. 19	Mar. 30	June 2	July 4	Oct. 22	....	Aug.
72	do	39	10	70	None.	Sandy loam	1902	25	Apr. 22	Apr. 26	....	....	....	July 5	Oct. 20	July 5	....
73	do	39	10	70	None.	do	1902	20	Apr. 25	May 1	....	Apr. 10	....	July 10	....	July 10	....
74	do	39	10	70	None.	do	1903	8	Apr. 17	Apr. 22	Apr. 6	....	....	July 20	Oct. 22	July 20	....
69	Maryland	39	15	50	None.	do	1904	14	Apr. 28	May 5	....	Apr. 28	....	....	....	....	....
87	New Jersey	39	15	40	SW.	do	1902	10	do	May 4	....	Apr. 23	....	....	....	July 7	....
67	Maryland	39	20	50	E.	do	1903	25	Apr. 9	Apr. 13	Apr. 6	Apr. 6	....	July 10	Oct. 26	July 20	....
65	do	39	20	75	....	do	1902	7	Apr. 22	Apr. 25	....	Mar. 27	....	July 14	....	July 14	July 28.
65	do	39	20	75	....	do	1903	......	Apr. 15	....	....	Apr. 1	....	....	....	....	....
60	do	39	35	75	SSW.	Heavy loam	1902	25	Apr. 28	May 2	May 28	Apr. 26	July 5	July 12	Nov. 15	July 10	....
60	do	39	35	75	SSW.	do	1903	26	Apr. 24	Apr. 29	Apr. 20	Apr. 2	....	....	Nov. –	....	....
60	do	39	35	75	SSW.	do	1904	27	May 5	May 9	May 11	Apr. 30	June 29	July 30	Sept. 17	....	Aug. 8.
79	New Jersey	39	35	90	NNW.	Gravelly loam	1902	50	Apr. 20	Apr. 25	Apr. 15	Apr. 16	....	July 12	Oct. 22	July 12	....
89	do	39	40	150	None.	do	1904	27	May 5	May 8	Apr. 17	Apr. 30	June 15	July 15	Sept. 25	July 15	....
91	do	39	50	....	....	....	1906	35	Apr. 26	Apr. 28	....	Apr. 14	July 20	July 20	....	July 10	Aug. 10.
82	do	39	55	50	W.	Sandy loam	1902	20	Apr. 20	Apr. 26	....	....	....	July 8	....	July 8	July 18.
96	do	40	15	90	N. & S.	Clay loam	1904	37	May 7	May 12	....	May 5	....	July 13	Sept. 17	July 13	....
96	do	40	15	90	N. & S.	do	1905	38	Apr. 30	May 4	....	Apr. 14	....	July 11	Oct. 18	July 11	....
96	do	40	15	90	N. & S.	do	1906	39	do	May 2	Apr. –	Apr. 20	....	July 10	Oct. –	July 15	....
94	do	40	20	140	SW.	Sandy loam	1905	41	Apr. 29	May 4	Apr. 19	....	....	July 10	....	July 10	July 30.
99	do	40	35	40	NW.	do	1907	12	May 9	May 12	May 12	May 1	....	....	Oct. 5	....	....

RED JUNE.

6	North Carolina	35	5	200	None.	Sandy	1902	......	Apr. 8	Apr. 16	....	Apr. 22	....	....	....	....	....
6	do	35	5	200	None.	do	1904	......	Mar. 31	Apr. 6	....	....	....	....	....	....	....
11	do	35	25	1,990	SE.	Porous loam	1904	20	Apr. 15	Apr. 20	Apr. 21	Apr. 30	....	July 1	Oct. 24	July 20	Aug. 10.
11	do	35	25	1,990	SE.	do	1906	22	Apr. 8	Apr. 16	May 10	Apr. 5	....	....	Oct. 10	....	....
12	do	35	25	2,130	W.	do	1902	25	Apr. 18	Apr. 26	Apr. 5	Apr. 14	July 1	July 1	Oct. 15	June 28	Aug. 25.
10	do	35	30	2,875	SW.	Clay loam	1903	12	Mar. 27	Apr. 10	Apr. 28	Apr. 2	July 10	July 25	Oct. 25	....	....
2	do	35	30	2,900	E.	do	1904	8	Apr. 16	Apr. 28	Apr. 20	Apr. 5	....	July 10	Oct. 14	....	....
2	do	35	30	2,900	E.	do	1905	9	Apr. 2	Apr. 13	Apr. 18	Apr. 3	June 20	July 1	Oct. 17	....	....
4	do	35	50	1,200	S.	Sandy loam	1904	20	Apr. 15	May 1	....	May 15	....	June 20	....	....	....
16	do	36	10	3,250	S.	Clay loam	1904	8	May 10	May 17	Apr. 21	Apr. 20	June 25	July 20	Oct. 15	July 20	Aug. 1.
16	do	36	10	3,250	S.	do	1905	9	Apr. 21	May 1	May 16	Apr. 15	July 23	do	Oct. 20	do	Do.
33	Virginia	37	0	5	None.	Sandy loam	1904	8	Apr. 19	Apr. 25	Apr. 20	Mar. 28	July 9	July 18	Oct. 17	July 18	July 24.
38	do	37	15	2,170	NW.	Limestone clay	1903	14	Apr. 15	Apr. 20	Apr. 5	Mar. 29	....	....	Sept. 14	July –	Aug.
30	do	37	20	950	SE.	Porous loam	1902	27	Apr. 10	Apr. 25	Apr. 12	....	....	July 5	Oct. 27	....	....
78	Delaware	38	45	50	None.	Sandy loam	1904	21	Apr. 24	May 3	Apr. 22	Apr. 13	....	....	....	....	....

TABLE IV.—*Phenological records—Apples*—Continued.

ROME BEAUTY.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
16	North Carolina	36 10	3,250	S.	Clay loam	1904	10	May 12	May 22	Apr. 21	Apr. 25	July 18	Oct. 10	Oct. 15	Nov. 25	May.
16	do	36 10	3,250	S.	do	1905	11	May 5	May 10	May 16	Apr. 20	July 21	do	Oct. 20	do	Do.
38	Virginia	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 3	Apr. 18	do			Sept. 14		
44	do	37 45	630	SW.	Loam	1904	12	Apr. 26		Apr. –	Apr. 6	June 15				
54	do	39 0	1,000	NE.	Sandy loam	1902	14	Apr. 25	Apr. 30	Apr. 14	Apr. 18	do	Sept 15		Sept. 25	Late.
54	do	39 0	1,000	NE.	do	1903	15	Apr. 13	Apr. 27	Apr. 5	Apr. 2	June 10	Sept. 25		Oct. 15	Jan.
54	do	39 0	1,000	NE.	do	1904	16	May 4	May 10	Apr. 20	Apr. 29	do				
54	do	39 0	1,000	NE.	do	1905	17	Apr. 21	Apr. 27	Apr. 19	Apr. 6	do	Sept. 20			Late.
54	do	39 0	1,000	NE.	do	1906	18	Apr. 27	May 2	May 8	Apr. 16	do	Sept. 25		Oct. 1	Apr.
54	do	39 0	1,000	NE.	do	1907	19	Apr. 26	Apr. 30	Apr. 23	Apr. 4	June 15	Sept. 15		do	Do.
57	do	39 10	600	NW.	Clay loam	1903	17	Apr. 18	Apr. 23							
98	New Jersey	40 30	600	S.	Red shale	1905	14		May 11	Apr. 16	Apr. 28		Sept. –	Oct. –		Feb.

ROXBURY. Synonym: *Roxbury Russet.*

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
38	Virginia	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 29	May 4	Apr. 18	Apr. 10			Sept. 14		
38	do	37 15	2,170	NW.	do	1903	14	Apr. 15	Apr. 28	Apr. 5	Mar. 27		Sept. 25	do	Oct. 15	Dec.
38	do	37 15	2,170	NW.	do	1904	15	May 5	May 12	May 16	Apr. 22	June 22		Oct. 15		
36	do	38 15	650		Sandy loam	1902	15	Apr. 20	Apr. 24	May 3	Apr. 23			Oct. 17		
48	do	38 45	375	SE.	Porous loam	1903	25	Apr. 9	Apr. 12	Apr. 5	Apr. 15	July 2	Sept. 15	Oct. 25		Dec.
48	do	38 45	375	SE.	do	1905	27	Apr. 24	Apr. 28	Apr. 19	Apr. 26					
48	do	38 45	375	SE.	do	1906	60	Apr. 27	Apr. 29	May 11	May 3			Oct. 11	Aug. 1	Dec.
48	do	38 45	375	SE.	do	1907		Apr. 28	Apr. 30	Apr. 20			Sept. 20	Oct. 13		Jan.
58	Maryland	39 35	300	S.	Limestone loam	1906	50	Apr. 30	May 4	May 10	Apr. 20		Oct. 1	Oct. 12	Oct. 1	Feb.
58	do	39 35	300	S.	do	1907	51	May 3	May 10	May 12	Apr. 23		Oct. 5	Oct. 15	do	Do.
60	do	39 35	75	SW.	Heavy loam	1902	25	Apr. 27	May 1	May 28	do	July 12	do	Nov. 15	Sept. 1	Late.
60	do	39 35	75	SW.	do	1903	26	Apr. 30	May 2	May 20	Apr. 3			Nov. –		
60	do	39 35	75	SW.	do	1904	27	May 7	May 9	May 11	May 1	June 30		Sept. 17		Late.
92	New Jersey	40 15	200	S.	Loam	1907	36	do	May 13	May 22	Apr. 27	June 18	Oct. 1	Oct. –	Jan.	Mar.
104	do	41 0	600	None.	Clay loam	1904	12	May 10	May 16	Apr. 23	May 4	July 2	Oct. 18	Sept. 22	Mar.	Apr.
104	do	41 0	600	None.	do	1905	14	May 6	May 10	Apr. 24	Apr. 27	July 3	Oct. 5	Oct. 22	Dec.	Do.
104	do	41 0	600	None.	do	1906	15			May 11	Apr. 26	June 28		Oct. 12		
104	do	41 0	600	None.	do	1907	16	May 14	May 18	May 12	Apr. 29	July 3	Oct. 18	Oct. 25	Dec.	Apr.

SHOCKLEY.

6	North Carolina	35	5	200	None.	Sandy loam	1902		Apr. 8	Apr. 20		Mar. 25					
6	do	35	5	200	None.	do	1904		Apr. 1	Apr. 7							
15	do	35	15	1,700	SE.	Porous loam	1903	8	do	do	Feb. –				Dec. –		
11	do	35	25	1,990	SE.	do	1904	15	Apr. 28	May 4	Apr. 21	May 10		Oct. 20	Oct. 24		
11	do	35	25	1,990	SE.	do	1905	12	May 1	May 8	May 6	do		Sept. 5	Oct. 18	Dec.	Mar.
11	do	35	25	1,990	SE.	do	1906	15	Apr. 15	Apr. 22	Mar. 10	Apr. 8		Oct. 10		Nov.	Jan.
11	do	35	25	1,990	SE.	do	1907	16	Apr. 10	May 1	Apr. 20	Apr. 20			Oct. 13		Feb.
13	do	35	25	2,180	NE.	do	1904	15	May 1	May 10	Apr. 17	Apr. 25	May 30	Oct. –	Oct. 15	Oct. –	Mar.
10*d*	do	35	30	4,500	SE.	Sandy loam	1903	12	May 2	May 8	Apr. 28	May 8	July 20	Oct. 1	Oct. 5	Oct. 19	Jan.
38	Virginia	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 30	May 3	Apr. 18	Apr. 10			Sept. 14		
38	do	37	15	2,170	NW.	do	1903	14	Apr. 15	Apr. 27	Apr. 5	Apr. 5		Sept. 30	do		
38	do	37	15	2,170	NW.	do	1904	15	May 6	May 10	May 16	Apr. 16	June 24		Oct. 15		
28	do	37	20	1,000	N.	Porous loam	1904	12	May 15	May 25	May 7	Apr. 17		Oct. 20		Oct. 20	
28	do	37	20	1,000	N.	do	1906	14	Apr. 17	Apr. 18	Mar. 29	Apr. 3	July 6		Nov. 20		
29	do	37	20	1,000		do	1903	4	Apr. 4	Apr. 10	Apr. 6	Apr. 18		Oct. 1		Dec.	Mar.
20	do	38	0	700	S.	Clay loam	1905	30	Apr. 10	Apr. 14	Apr. 18	May 28					

SMITH CIDER.

33	Virginia	37	0	5	SW.	Sandy loam	1904	8	Apr. 19	Apr. 26	Apr. 20	Apr. 1	Aug. 12	Aug. 28	Oct. 17		
38	do	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 2	Apr. 18	Apr. 11		Sept. 15	Sept. 14		
38	do	37	15	2,170	NW.	do	1903	14	Apr. 15	Apr. 20	Apr. 5	Mar. 28		Sept. 25	do	Oct.	
38	do	37	15	2,170	NW.	do	1904	15	May 1	May 8	May 16	Apr. 21	June 20		Oct. 15		
37	do	39	10	600	NW.	Clay loam	1903	17	Apr. 13	Apr. 21							
68	Maryland	39	10	550	S.	do	1906	9	Apr. 21	May 1	May 10	Apr. 18		Oct. 1	Oct. 12	Nov. 15	Jan.
65	do	39	20	75		Gravelly loam	1902	9	Apr. 23	Apr. 25		Mar. 29		Oct. 6		Oct. 6	Nov.
65	do	39	20	75		do	1903	10	Apr. 15			Mar. 28				Oct. 1	Dec.
64	do	39	25	225	SE.	Stony loam	1905	25	Apr. 25	Apr. 30	Apr. 19	Apr. 22	Sept. 15	Sept. 1	Oct. 19	Sept. 20	Do.
64	do	39	25	225	SE.	do	1906	26	Apr. 30	May 3	May 10	May 3	Sept. 1		Oct. 11		
64	do	39	25	225	SE.	do	1907	29	Apr. 25	May 7	May 5	Apr. 25			Oct. 17		
60	do	39	35	75	SW.	Heavy loam	1902	11	Apr. 27	May 2	May 28	Apr. 23	July 8	Oct. 5			
60	do	39	35	75	SW.	do	1903	26	Apr. 29	do	Apr. 20	Apr. 5					
60	do	39	35	75	SW.	do	1904	27	May 8	May 12	May 11	Apr. 29	June 30	Oct. 10			
79	New Jersey	39	35	90	NW.	Gravelly loam	1902	50	Apr. 21	Apr. 26	Apr. 15	Apr. 18		Sept. 15			
89	do	39	40	150	None.	Porous loam	1904	25	May 5	May 10	Apr. 17	May 1	June 15	Sept. 26	Sept. 25	Feb.[a]	
59	Maryland	39	40	300		Clay loam	1902	20	Apr. 26	Apr. 28	Apr. 15						
82	New Jersey	39	55	50	W.	Sandy loam	1902	20	Apr. 24	Apr. 29				Sept. 20		Sept. 20	Jan.
86	do	40	0	50	NW.	Loam	1905	20	May 1	May 7		May 10	July 1	Nov. –	Nov. –	Nov. 1	Late.
85	do	40	0	75	S.	Sandy loam	1907	50	May 5	May 10	May 12			Oct. 9	Oct. 19		Do.
96	do	40	15	90	N. & S.	Clay loam	1904	25	May 9	May 14		May 7		Oct. 15	Sept. 17	Oct. 15	Jan.
96	do	40	15	90	N. & S.	do	1905	26	May 1	May 6		Apr. 15		Oct. 13	Oct. 18	Jan.	Feb.
96	do	40	15	90	N. & S.	do	1906	27	do		Apr. –	Apr. 21		Oct. 18	Oct. –	Nov. 1	Do.
92	do	40	15	200	SE.	do	1906	35	Apr. 26	May 4	May 10			Oct. 15	Oct. –	Oct.	Apr.
92	do	40	15	200	SE.	do	1907	36	May 7	May 12	May 22	Apr. 27	June 15	Oct. 1	Oct. 15	Nov.	Do.
94	do	40	20	140	S.	Sandy loam	1902	38	Apr. 24	Apr. 29	Apr. 28	Apr. 20	June 27	do	Oct. 10	do	Dec.
94	do	40	20	140	S.	do	1903	39	Apr. 26	May 1	May –	Apr. 9	June 13	do	Oct. –	Sept.	Feb.

[a] From cold storage.

TABLE IV.—*Phenological records—Apples*—Continued.

SMITH CIDER—Continued.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
94	New Jersey	40	20	140	S.	Sandy loam	1904	40	May 6	May 11		Apr. 25	July 16	...do...	Sept. 20	Oct.	Mar.
94	...do	40	20	140	S.	...do	1905	41	May 1	May 5	Apr. 19			Oct. –		...do...	Do.
94	...do	40	20	140	S.	...do	1906	42	May 2	May 9	May –	Apr. 20	June 5	...do...	Oct. –	...do...	Jan.
94	...do	40	20	140	S.	...do	1907	43	May 8	May 12		May 22	July 3	...do...	Oct. 20	...do...	Feb.
98	...do	40	30	600	S.	Red shale	1905	14	May 3	May 9	Apr. 16	Apr. 23		Oct. 1	Oct. –		Mar.
100	...do	40	35	600	N.	Clay loam	1903	19	Apr. 22	Apr. 27							
100	...do	40	35	600	N.	...do	1904	20	May 8	May 14	Apr. 22	Apr. 27					
104	...do	41	0	600	None.	...do	1904	12	May 10	...do...	Apr. 23	May 2	July 7	Oct. 20	Sept. 22	Feb.	Apr.
104	...do	41	0	600	None.	...do	1906	15	May 9	...do...	May 11	Apr. 22	July 4	...do...	Oct. 12	...do...	Do.
104	...do	41	0	600	None.	...do	1907	16	May 15	May 20	May 12	Apr. 27	July 1	Oct. 26	Oct. 25	Dec.	May.

SMOKEHOUSE.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
[illegible]	Virginia	37	15	2,170	NW.	Limestone clay	1902	13	Apr. 24	May 2	Apr. 18	Apr. 13			Sept. 14		
[illegible]	...do	37	20	1,200	W.	Porous loam	1902	25	Apr. 16	Apr. 24		Apr. 4					
[illegible]	...do	37	25	1,400	NW.	Gravelly loam	1902	6	Apr. 20	...do...	Apr. 8	Apr. 21	July –	Sept. 25		Oct. 25	Dec.
[illegible]	...do	37	55	200	E.&W.	Sandy loam	1903	16	Mar. 30	Apr. 4		Apr. 5		Aug. 20		Aug. 20	Sept.
[illegible]	...do	38	30	400	NE.	Red clay	1902	15	Apr. 23	Apr. 25	Apr. 15	Apr. 4	Aug. 20	July 26	Oct. 22	July 19	Do.
[illegible]	...do	38	30	400	NE.	...do	1903	16	Apr. 1	Apr. 10	Apr. 5	Mar. 22	Aug. 7		Oct. 18	July 11	Dec.
[illegible]	...do	38	30	400	NE.	...do	1904	17	Apr. 27	May 2	Apr. 23	Apr. 5	Aug. 2		Sept. 23	Aug. 1	Sept.
[illegible]	...do	38	30	400	NE.	...do	1905	18	Apr. 12	Apr. 19	Apr. 20	Mar. 28	July 17	Aug. 10	Oct. 13	July 15	Do.
[illegible]	...do	38	30	400	NE.	...do	1906	19	Apr. 19	Apr. 25	May 10	Apr. 9	July 29		Oct. 11	July 22	Do.
48	...do	38	45	375	S.	Porous loam	1906	30	Apr. 27	Apr. 29	May 11	Apr. 30			...do...	July 25	Do.
[illegible]	...do	39	0	600	E.	...do	1907	14	Apr. 20	May 1	May 9	Mar. 26		Sept. 1	Oct. 10	Oct.	Dec.
[illegible]	...do	39	10	600	NW.	Clay loam	1903	17	Apr. 14	Apr. 20							
60	Maryland	39	35	75	SW.	Heavy loam	1902	25	Apr. 27	May 2	May 28	Apr. 22	July 10	Sept. 16	Nov. 15	July 15	
60	...do	39	35	75	SW.	...do	1903	26	Apr. 25	Apr. 28	Apr. 20	Apr. 3			Nov. –		
60	...do	39	35	75	SW.	...do	1904	27	May 9	May 10	May 11	Apr. 29	June 30		Sept. 17		
60a	...do	39	35	125	SW.	Sandy loam	1902	35	Apr. 26	Apr. 28	Apr. 20	Apr. 20	July 10	Aug. 25	Nov. 15	July 1	Dec.
60a	...do	39	35	125	SW.	...do	1903	36	Apr. 15	Apr. 23	...do...	Apr. 1		Oct. 3	Nov. –		Do.
60a	...do	39	35	125	SW.	...do	1904	37	Apr. 30	May 7	Apr. 21	Apr. 22	July 5	Sept. 29	Sept. 17		Do.
85	...do	40	0	75	None.	...do	1907	50	May 1	May 6	May 12			Oct. 9	Oct. 19	Sept. 5	Oct.
82	New Jersey	39	55	50	W.	...do	1902	6	Apr. 23	Apr. 29				Sept. 1		Sept. 1	Do.
82	...do	39	55	50	W.	...do	1903	7	Apr. 16								
84	...do	39	55	50	N.	Heavy loam	1902	35	Apr. 25	Apr. 30	Apr. 16	Apr. 18	Aug. 15	Sept. 1	Oct. 10	Sept. 10	Jan.
84	...do	39	55	50	N.	...do	1903	36	Apr. 20	Apr. 25	May 2	Apr. 5	Aug. 1	...do...	Oct. –	Sept. 1	Do.
86	...do	40	0	50	NW.	Loam	1905	20	May 1	May 6		May 10	July 1	Sept. 15	Nov. –	Sept. 15	Nov.

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48	Virginia	38	45	350	SE.	Porous loam	1907		Apr. 26	Apr. 28	Apr. 20				Oct. 13		
75	Delaware	39	0	60	None.	Sandy loam	1906	10	Apr. 22	do.	Apr. 3	Apr. 18		Oct. 1	Oct. –	Nov.	Jan.
72	do.	39	10	70	None.	do.	1902	10	Apr. 23	Apr. 26				Oct. 10	Oct. 10	Nov. 1	
68	Maryland	39	10	550	S.	Porous loam	1906	9	Apr. 19	May 1	May 10	Apr. 15		Oct. 1	Oct. 12	Nov. 15	May.
65	do.	39	20	75		Gravelly loam	1902	7	Apr. 23	Apr. 28		Mar. 9		Oct. 13		Oct. 6	Jan.
65	do.	39	20	75		do.	1903	8	Apr. 15	Apr. 22		May 28				Nov. 15	Feb.
82	New Jersey	39	55	50	W.	Sandy loam	1902	6	Apr. 24	Apr. 30				Sept. 25		Sept. 25	Jan.

SUMMER HAGLOE. Synonym: *Hagloe.*

72	Delaware	39	10	70	None.	Sandy loam	1902	10	Apr. 26	Apr. 29				Aug. 1	Oct. 20	Aug. 10	
89	New Jersey	39	40	150	None.	Gravelly loam	1904	25	May 8	May 12	Apr. 17	May 5	June 15	do.	Sept. 25	Aug. 1	
82	do.	39	55	50	W.	Sandy loam	1902	19	Apr. 24	Apr. 29				July 17		July 17	Aug.
82	do.	39	55	50	W.	do.	1903	20	Apr. 21								
80	do.	40	5	60	N.	Gravelly loam	1904	40	May 6	May 19	Apr. 24		June 1	Aug. 25	Oct. 10	Aug. 10	

TETOFSKI.

38	Virginia	37	15	2,170	NW.	Limestone clay	1903	14	Apr. 13	Apr. 26	Apr. 15	Apr. 11			Sept. 14		
38	do.	37	15	2,170	NW.	do.	1904	15	May 6	May 13	May 16	Apr. 22	July 2		Oct. 15		
100	New Jersey	40	35	600	N.	Clay loam	1903	19	Apr. 25			Apr. 1					
100	do.	40	35	600	N.	do.	1904	20	May 3	May 12	Apr. 22	Apr. 27		Aug. 9		Aug. 10	Aug. 15.

TOMPKINS KING. Synonym: *King.*

38	Virginia	37	15	2,170	NW.	Limestone clay	1903	14	Apr. 14	Apr. 20	Apr. 5	Apr. 17		Sept. 20	Sept. 14		
38	do.	37	15	2,170	NW.	do.	1904	15	May 8	May 12	May 16	Apr. 19	June 25		Oct. 15		
48	do.	38	45	375	S.	Porous loam	1906	30	Apr. 26	Apr. 28	May 11	May 1			Oct. 11		Oct.
54	do.	39	0	1,000	NE.	do.	1902	8	Apr. 24	do.	Apr. 14	Apr. 14	June 20	Sept. 20		Nov. 1	
104	New Jersey	41	0	600	None.	Clay loam	1904	12	May 10	May 14	Apr. 23	May 3	July 2	Sept. 30	Sept. 22	do.	Jan.
104	do.	41	0	600	None.	do.	1906	15	May 8	May 13	May 11	Apr. 22	June 30	Oct. 1	Oct. 12	Feb.	Apr.
104	do.	41	0	600	None.	do.	1907	16	May 14	May 20	May 12	Apr. 26	July 7	do.	Oct. 25	Nov.	Feb.
101	do.	41	10	550	SE.	Gravelly loam	1904	18	May 8	May 15	Apr. 23	Apr. 24			Sept. 22		
102	do.	41	10	800	None.	Sandy loam	1904	23	May 10	do.							
102	do.	41	10	800	None.	do.	1905	24	May 7	May 11		Apr. 18					

TABLE IV.—*Phenological records—Apples*—Continued.

Observer number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
		° ′														
					VIRGINIA BEAUTY.											
10	North Carolina....	35 30	2,875	S.	Clay loam.........	1902	12	Apr. 28	May 8	Apr. 1	May 4	July 30	Oct. 20	Oct. 15	Dec. 1	Feb.
18	do....	35 30	4,000	NE.	do............	1902	6	...do....	May 6	Apr. 25	May 7	July 24	Oct. 10	Oct. 3	Nov. 25	Dec.
107	do....	35 30	4,500	SE.	Sandy loam.......	1902	12	May 1	...do....	Apr. 22	....	July 27	Oct. 21	Oct. 1	Dec. 1	Jan.
4	do....	35 50	1,200	S.	.....do............	1904	12	Apr. 15	May 1	....	May 15	....	Oct. –	....	Sept. –	....
16	do....	36 10	3,250	S.	Clay loam.........	1904	10	May 8	May 15	Apr. 21	Apr. 24	July 29	Oct. 5	Oct. 15	Nov. 1	Feb.
					WEALTHY.											
38	Virginia......	37 15	2,170	NW.	Limestone clay...	1903	14	Apr. 15	Apr. 27	Apr. 5	Mar. 30	....	Sept. 20	Sept. 14	Oct. 5	....
38	.....do.......	37 15	2,170	NW.	.....do...........	1904	15	May 6	May 13	May 16	Apr. 21	June 27	....	Oct. 15	....	....
72	Delaware......	39 10	70	None.	Sandy loam.......	1902	7	Apr. 25	Apr. 28	....	....	....	Sept. 5	Oct. 20	....	....
82	New Jersey...	39 55	50	W.	.....do...........	1902	6	Apr. 24	Apr. 27	....	....	....	Aug. 15	....	Aug. 15	Sept. 15.
					WILLIAMS.											
38	Virginia............	37 15	2,170	NW.	Limestone clay....	1903	14	Apr. 16	Apr. 29	Apr. 5	Mar. 30	....	....	Sept. 14	....	....
38	.....do...........	37 15	2,170	NW.	.....do...........	1904	15	May 7	May 14	May 16	Apr. 26	June 28	....	Oct. 15	....	....
76	Delaware........	39 5	40	NE.	Sandy loam.......	1903	12	Apr. 20	Apr. 28	Apr. 6	Apr. 1	June 16	July 13	....	....	July. 27.
76	.....do...........	39 5	40	NE.	.....do...........	1904	13	May 5	May 7	Apr. 21	Apr. 28	June 23	July 23	Oct. 28	July 28	....
76	.....do...........	39 5	40	NE.	.....do...........	1905	14	Apr. 26	Apr. 29	Apr. 19	Apr. 4	June 14	July 24	Oct. 22	....	....
72	.....do.............	39 10	70	None.	.....do...........	1902	7	Apr. 25	Apr. 28	....	....	....	July 10	Oct. 20	July 10	....
82	New Jersey.........	39 55	50	W.	.....do...........	1902	6	Apr. 24	Apr. 30	....	....	....	July 15	....	July 11	Aug. 1.
86	.....do.............	40 0	50	NW.	Loam.............	1905	20	May 1	May 7	....	....	July 1	July 25	Nov. –	July 15	Do.
80	.....do.............	40 5	60	N.	Gravelly loam....	1904	24	May 7	....	Apr. 24	....	June 1	July 15	Oct. 10	...do....	....
80	.....do.............	40 5	60	N.	.....do...........	1905	25	May 1	May 5	Apr. 19	Apr. 21	June 15	July 25	Oct. 15	July 25	....
80	.....do.............	40 5	60	N.	.....do...........	1906	26	Apr. 29	...do....	Apr. 6	....	June 14	Aug. 1	....	July 14	....
80	.....do.............	40 5	60	N.	.....do...........	1907	30	May 10	May 20	Apr. 20	Apr. 27	July 1	July 25	....	....	....
99	.....do.............	40 35	40	NW.	Sandy loam.......	1907	25	...do....	May 14	May 12	May 3	Sept. 15	July 30	Oct. 5	July –	Aug.

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15	North Carolina......	35	15	1,700	SE.	Porous loam......	1903	8	Apr. 3	Apr. 11	Feb. –	......	......	......	Dec. –	......	......
7	....do....	35	20	700	None.	Loam....	1905	10	Mar. 25	Apr. 5	Apr. 17	Mar. 18	......	......	Oct. 11	......	......
11	....do....	35	25	1,990	SE.	Porous loam......	1904	20	Apr. 28	May 3	Apr. 21	May 8	......	Oct. 10	Oct. 24	Nov. 1	Dec.
11	....do....	35	25	1,990	SE.	.....do......	1906	22	Apr. 10	Apr. 18	May 10	Apr. 5	......	...do....	Oct. 10	...do....	Jan.
11	....do....	35	25	1,990	SE.	.....do......	1907	15	...do....	May 1	Apr. 20	Apr. 15	......	......	Oct. 13	......	Dec.
12	....do....	35	25	2,130	W.	.....do......	1902	17	Apr. 24	...do....	Apr. 5	Apr. 22	July 4	Sept. 30	Oct. 15	Oct. 15	May.
12	....do....	35	25	2,130	W.	.....do......	1903	18	Apr. 8	Apr. 13	Apr. 6	Apr. 13	July 6	......	......	......	......
12	....do....	35	25	2,130	W.	.....do......	1904	19	Apr. 17	Apr. 28	Apr. 11	Apr. 27	......	Oct. 1	Oct. 15	Dec. 20	Apr.
12	....do....	35	25	2,130	W.	.....do......	1905	20	Apr. 6	Apr. 14	Apr. 7	Apr. 20	July 24	...do....	Oct. 14	Dec. –	Do.
13	....do....	35	25	2,180	NE.	Porous clay......	1904	15	May 1	May 10	Apr. 17	Apr. 25	May 30	Oct. -	Oct. 15	Sept. 15	Mar.
2	....do....	35	30	2,900	E.	Clay loam......	1904	8	Apr. 17	Apr. 28	......	Apr. 7	......	Nov. 12	Oct. 14	......	......
2	....do....	35	30	2,900	E.	.....do......	1905	9	Apr. 5	Apr. 13	Apr. 18	Apr. 3	July 24	......	Oct. 17	......	......
10	....do....	35	30	2,875	SW.	.....do......	1902	12	Apr. 30	May 10	Apr. 1	May 5	July 31	Oct. 15	Oct. 15	Dec. 25	Feb.
10	....do....	35	30	2,875	SW.	.....do......	1903	7	Apr. 4	Apr. 14	Apr. 28	Apr. 1	July 12	...do....	Oct. 25	Dec. 10	Do.
10	....do....	35	30	2,875	SW.	.....do......	1904	8	Apr. 15	Apr. 25	Apr. 1	Mar. 23	June 30	Oct. 20	Oct. 16	Nov. 1	Do.
10	....do....	35	30	2,875	SW.	.....do......	1905	9	......	......	Mar. 10	Mar. 28	July 2	...do....	......	Dec. 10	......
10	....do....	35	30	2,875	SW.	.....do......	1906	10	Mar. 28	Apr. 10	Apr. 15	...do....	July 15	Nov. 15	Oct. 11	Dec. –	Mar.
10a	....do....	35	30	3,300	NE.	.....do......	1902	6	Apr. 21	Apr. 27	...do....	Apr. 21	July 31	Oct. 20	Oct. 5	Nov. 20	Jan.
10b	....do....	35	30	3,500	SE.	Gravelly clay......	1902	12	Apr. 29	May 8	Apr. 20	May 7	July 30	...do....	Oct. 3	Dec. 20	Mar.
10c	....do....	35	30	4,000	NE.	Clay loam......	1902	6	May 1	...do....	Apr. 25	May 9	July 26	Oct. 15	...do....	Dec. 1	Feb.
10d	....do....	35	30	4,500	SE.	Sandy loam......	1902	13	Apr. 25	May 3	Apr. 22	May 8	July 30	Oct. 20	Oct. 1	Nov. 20	Jan.
10d	....do....	35	30	4,500	SE.	.....do......	1903	14	May 3	May 10	Apr. 28	May 9	July 18	...do....	Oct. 5	Dec. 1	May.
1	....do....	35	35	2,300	S.	Loam......	1904	12	Apr. 15	Apr. 28	......	Apr. 3	......	......	Oct. 15	......	......
1	....do....	35	35	2,300	S.	.....do......	1905	13	Apr. 5	Apr. 15	Apr. 16	Mar. 27	......	Oct. 15	Oct. 16	Jan. 1	......
4	....do....	35	50	1,200	S.	Sandy loam......	1904	20	Apr. 15	May 1	......	May 15	......	......	......	......	......
5	....do....	35	50	1,500	N.	Loam......	1905	20	...do....	Apr. 20	Mar. 30	Mar. 25	May 5	Oct. 25	Oct. -	Oct. 10	Apr.
8	....do....	36	5	900	S.	Sandy......	1905	15	Apr. 3	...do....	......	......	......	......	......	......	......
47	Virginia....	36	45	1,700	SE.	Black loam......	1905	......	Apr. 15	May 1	May 1	......	......	Sept. 25	......	Nov. 1	Apr.
33	....do....	37	5	5	SW.	Sandy loam......	1903	7	......	......	Apr. 5	Mar. 25	Aug. 20	......	Oct. 27	......	......
33	....do....	37	5	5	SW.	.....do......	1904	8	Apr. 24	Apr. 29	Apr. 20	Apr. 4	June 23	Aug. 15	Oct. 17	......	......
48	....do....	37	5	......	......	......	1907	21	Apr. 29	May 8	...do....	Apr. 30	......	Sept. 28	Oct. 15	Sept. 15	Mar.
40	....do....	37	10	2,400	None.	Porous loam......	1907	8	Apr. 10	Apr. 26	Apr. 5	......	......	......	......	......	......
39	....do....	37	10	2,000	NW.	Dark loam......	1902	8	Apr. 25	May 3	May 18	......	......	Oct. 20	Sept. 10	Jan. 10	Apr.
26	....do....	37	15	900	N.	Sandy loam......	1902	15	Apr. 21	Apr. 26	......	......	June 20	......	......	Jan. 25	......
26	....do....	37	15	900	N.	.....do......	1903	16	Apr. 4	Apr. 12	......	......	......	......	......	......	......
46	....do....	37	15	500	S.	.....do......	1903	16	Apr. 1	......	......	......	......	......	......	Sept. 20	Mar.
38	....do....	37	15	2,170	NW.	Limestone clay......	1902	13	Apr. 28	May 3	Apr. 18	Apr. 12	......	Sept. 25	Sept. 14	......	......
38	....do....	37	15	2,170	NW.	.....do......	1903	14	Apr. 30	May 15	Apr. 5	Apr. 5	......	Sept. 30	...do....	......	......
38	....do....	37	15	2,170	NW.	.....do......	1904	15	May 7	May 12	May 16	Apr. 23	June 24	......	Oct. 15	......	......
28	....do....	37	20	1,000	N.	Porous loam......	1904	5	May 15	May 25	May 7	......	......	Oct. 20	......	Oct. 20	Late.
28	....do....	37	20	1,000	N.	.....do......	1905	10	Apr. 6	Apr. 20	Mar. 28	Apr. 3	June 19	Sept. 24	Oct. 13	...do....	Do.
28	....do....	37	20	1,000	N.	.....do......	1906	11	Apr. 12	Apr. 21	May 29	Apr. 10	July 10	......	Nov. 20	......	......
28	....do....	37	20	1,000	N.	.....do......	1907	12	Apr. 4	Apr. 27	May 7	Mar. 27	June 18	Oct. 8	Nov. 4	Oct. 25	Late.
22	....do....	37	20	1,200	W.	Clay loam......	1902	20	Apr. 17	Apr. 25	......	Apr. 10	......	......	......	......	......
25	....do....	37	20	1,000	SE.	.....do......	1902	15	Apr. 15	Apr. 20	Mar. 20	Apr. 15	July 15	Oct. 15	Oct. 20	Dec. 1	Apr.
25	....do....	37	20	1,000	SE.	.....do......	1903	16	Apr. 20	May 1	Apr. 20	Apr. 20	July 20	Oct. 10	Oct. 15	Nov. 15	Do.
25	....do....	37	20	1,000	SE.	.....do......	1904	17	May 1	May 10	May 5	May 1	July 10	...do....	Oct. 10	...do....	Do.
25	....do....	37	20	1,000	SE.	.....do......	1905	18	Apr. 25	May 5	Apr. 15	Apr. 25	July 20	Oct. 20	Oct. 20	...do....	Do.

TABLE IV.—*Phenological records—Apples*—Continued.

WINESAP Continued.

Observer's number.	State.	Approximate latitude.		Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
24	Virginia	37	20	1,200	SE.	Porous loam	1903	10	Apr. 7	Apr. 16	Apr. 6	Apr. 20		Oct. 1		Oct. –	Feb.
1	do	37	25	1,400	NW.	Gravelly loam	1902	12	Apr. 24	Apr. 26	Apr. 8	Apr. 23	July –	Sept. 28		Nov. 15	Late.
27	do	37	30	1,000	NE.	Clay loam	1902	26	Apr. 19	Apr. 22	Mar. –	Apr. 9		Sept. 25	Nov. –	Nov. –	Feb.
44	do	37	45	630	SW.	Loam	1904	12	Apr. 25		Apr. –	Apr. 4	June 15				
42	do	37	45	800	SE.	Clay loam	1903	2	Apr. 4	Apr. 15	Apr. 15	Apr. 25		Sept. 15		Dec. 15	June.
43	do	37	50	1,000	SE.	do	1903	6	Apr. 5	Apr. 18	Apr. 5	Apr. 20	June 1	Oct. 10	Oct. 27	Oct. –	May.
45	do	37	59	1,000			1906	15	Apr. 16	Apr. 20	May 9	Apr. 10		Oct. 1	Oct. 10	Nov.	Do.
[illegible]	do	37	50	1,000			1907	26	Apr. 1	do	Apr. –			do		Dec.	Apr.
21	do	37	55	500	SE.	Clay	1904	20	Apr. 24	Apr. 26		Apr. 10		Sept. 1			
20	do	38	0	700	S.	do	1905	30	Apr. 10	Apr. 14	Apr. 18	Mar. 29					
41	do	38	0	1,200	N.	Clay loam	1903	19	Apr. 5	Apr. 11	Apr. 5	Mar. 25		Oct. 14	Oct. 15	Dec. 15	Apr.
71	Maryland	38	5	20	SE.	Red clay	1902	8		Apr. 27		Apr. 10		Nov. 1		Dec. 1	Feb.
19	Virginia	38	5	900	S.	do	1905	8	Apr. 13	Apr. 23	Apr. 19	Apr. 2		Sept. 19	Oct. 7	Oct. –	
19	do	38	5	900	S.	do	1905	19	Apr. 11	Apr. 22	do	Mar. 29		do	do	do	
18	do	38	10	1,000	W.	Sandy loam	1902	16						Sept. 25	Oct. 5	Nov. 15	Feb.
18	do	38	10	1,000	W.	do	1903	17	Apr. 4	Apr. 13	Apr. 7	Apr. 30		Oct. 1	Oct. 20	Nov. 1	Dec.
22	do	38	10	1,200	NE.	Gravelly loam	1907	20	Apr. 23	Apr. 30	May 22	Mar. 28		Oct. 15	Oct. 9	Feb. –	Apr.
36	do	38	15	650		Sandy loam	1902	15	Apr. 18	Apr. 23	May 3	Apr. 18			Oct. 17		
53	do	38	25	1,400	W.	Gravelly loam	1902	16	Apr. 26	Apr. 30		Apr. 14		Sept. 30		Dec. –	Mar.
53	do	38	25	1,400	W.	do	1903	17	Apr. 12	Apr. 22		Apr. 8		Oct. –		do	Do.
53	do	38	25	1,400	W.	do	1905	19	Apr. 21	Apr. 27	Apr. 24	Apr. 6		Oct. 1		Oct. –	Do.
53	do	38	25	1,400	W.	do	1906	20	Apr. 25	May 2	May 11	Apr. 17		do	Oct. 8	do	Do.
35	do	38	30	400	NE.	Red clay	1902	15	Apr. 23	Apr. 27	Apr. 15	Apr. 16	Aug. 16	Oct. 15	Oct. 22	Oct. 1	Apr.
35	do	38	30	400	NE.	do	1903	16	Apr. 7	Apr. 14	Apr. 5	Mar. 27	Aug. 5	Oct. 1	Oct. 18	Sept. 1	Do.
35	do	38	30	400	NE.	do	1904	17	May 1	May 6	Apr. 23	Apr. 9	Aug. 4	Sept. 26	Sept. 23	do	Do.
35	do	38	30	400	NE.	do	1905	18	Apr. 13	Apr. 21	Apr. 20	Mar. 31	July 18		Oct. 13	do	Do.
35	do	38	30	400	NE.	do	1906	19	Apr. 22	Apr. 29	May 10	Apr. 11	July 29		Oct. 11	do	Do.
61	Maryland	38	40	45	None.	Sandy loam	1907	15	Apr. 15	Apr. 28							
78	Delaware	38	45	50	SE.	do	1904	21	Apr. 29	May 4	Apr. 22	Apr. 13					
34	Virginia	38	45	300	W.	Clay loam	1902	13			May 30			Oct. 18	Sept. 18	Sept. 1	Jan.
48	do	38	45	375	SE.	Porous loam	1903	15	Apr. 10	Apr. 15	Apr. 5	Apr. 18	June 30	Sept. 15	Oct. 25	Jan. –	Mar.
48	do	38	45	375	SE.	do	1906	33	Apr. 27	Apr. 29	May 11	May 2			Oct. 11	Sept. 1	Do.
48	do	38	45	375	SE.	do	1907	34	do	Apr. 30	Apr. 20				Oct. 13		
54	do	39	0	1,000	NE.	do	1902	14	Apr. 24	Apr. 29	Apr. 14	Apr. 17	June 15	Sept. 25		Sept. 1	Late.
54	do	39	0	1,000	NE.	do	1903	15	Apr. 10	Apr. 22	Apr. 5	May 30	June 10	Sept. 30		Dec. 1	Do.
54	do	39	0	1,000	NE.	do	1904	16	May 3	May 9	Apr. 20	Apr. 27	do				

54	do.	39	0	1,000	NE.	do.	1905	17	Apr. 19	Apr. 26	Apr. 19	Apr. 10	do.				
54	do.	39	0	1,000	NE.	do.	1906	18	Apr. 25	Apr. 30	May 8	Apr. 18	do.	Oct. 1		Oct. 1	Apr.
54	do.	39	0	1,000	NE.	do.	1907	19	Apr. 20	Apr. 26	Apr. 23	Mar. 30	do.	do.		Dec. 1	June.
55	do.	39	0	600	E.	Sandy loam	1907	14	Apr. 21	Apr. 25	May 8	Mar. 29		do.	Oct. 10	Jan. –	Mar.
57	Maryland	39	0	75	None.	Sandy	1907	25	Apr. 20	May 6	Apr. 18	Apr. 4					
72	Delaware	39	10	70	None.	Sandy loam	1902	30	Apr. 24	Apr. 26				Oct. 25	Oct. 20	Nov. 15	
73	do.	39	10	100	N.	do.	1902	20	Apr. 28	May 4		Apr. 10		Nov. 1		Dec. 20	Jan.
74	do.	39	10	80	None.	Clay loam	1903	14	Apr. 18	Apr. 25	Apr. 6			Oct. 1	Oct. 22	Dec. –	
37	Virginia	39	10	600	NW.	do.	1903	17	Apr. 17	Apr. 23							
87	New Jersey	39	15	40	SW.	Sandy loam	1902	10	Apr. 30	May 7		Apr. 24					
67	Maryland	39	20	50	E.	do.	1903	8	Apr. 10	Apr. 15	Apr. 6	Apr. 7		Oct. 15	Oct. 26	Nov. 1	Dec.
64	do.	39	25	225	SE.	Stony loam	1905	25	Apr. 28	Apr. 30	Apr. 19	Apr. 26	Sept. 1	do.	Oct. 19	Dec. 15	Mar.
64	do.	39	25	225	SE.	do.	1906	26	Apr. 30	May 3	May 10	May 2	Aug. 15		Oct. 11		
64	do.	39	25	225	SE.	do.	1907	27	Apr. 28	May 8	May 5	May 1			Oct. 17		
60	do.	39	35	75	SW.	Heavy loam	1902	25	do.	May 1	May 28	Apr. 23	July 12	Sept. 16	Nov. 15	Sept. 1	Late.
60	do.	39	35	75	SW.	do.	1903	26	Apr. 30	May 2	Apr. 20	Apr. 3			Nov. –		
60	do.	39	35	75	SW.	do.	1904	27	May 6	May 9	May 11	May 2	July 4	Oct. 5	Sept. 17		Late.
79	New Jersey	39	35	90	NNW.	Gravelly loam	1902	50	Apr. 24	Apr. 29	Apr. 15	Apr. 21		Sept. 20	Nov. 15	Sept. 10	
89	do.	39	40	150	None.	do.	1904	10	May 8	May 12	Apr. 17	May 4	June 15	Oct. 1	Sept. 25	Apr. 1[a]	
91	do.	39	50				1906	3	Apr. 30	May 1		Apr. 14	July 20	Oct. 15		Oct. 1	Apr.
82	do.	39	55	50	W.	Sandy loam	1902	20	Apr. 24	Apr. 28				Sept. 25		Sept. 25	Dec.
94	do.	40	20	140	S.	do.	1902	38	do.	May 1	Apr. 28	Apr. 20	June 27	Oct. 1	Oct. 10	Nov. –	Feb.
94	do.	40	20	140	S.	do.	1904	40	May 8	May 11		Apr. 30	July 16	do.	Sept. 20	Dec. –	Apr.
94	do.	40	20	140	S.	do.	1905	41	Apr. 30	May 4	Apr. 19			Oct. –		Sept. –	Do.
94	do.	40	20	140	S.	do.	1906	42	May 3	May 8		Apr. 21	June 5	Oct. 1	Oct. –	Oct. –	June.
94	do.	40	20	140	S.	do.	1907	43	May 1	May 14		Apr. 26	July 4	Nov. 1	Oct. 20	do.	Feb.
99	do.	40	35	40	NW.	do.	1907	12	May 12		May 12	May 1		Oct. 15	Oct. 5		May.
104	do.	41	0	600	None.	Clay loam	1905	16	May 7	May 11	Apr. 24	Apr. 25	July 1	Oct. 17	Oct. 22	Jan. 1	Do.

WINTER PARADISE. Synonym: *Sweet Winter Paradise.*

28	Virginia	37	20	1,000	N.	Clay loam	1904	12	May 12	May 18	May 7			Oct. 20		Sept. 15	
29	do.	37	20	1,200	SE.	do.	1903	25	Apr. 10	Apr. 15	Apr. 6	Apr. 15		Aug. 20		Oct. –	Dec.
35	do.	38	30	400	NE.	Red clay	1902	15	Apr. 20	Apr. 27	Apr. 15	Mar. 31	Aug. 10	Sept. 26	Oct. 22	Sept. 1	Jan.
35	do.	38	30	400	NE.	do.	1903	16	Mar. 31	Apr. 5	Apr. 5	Mar. 23	Aug. 1	Sept. 15	Oct. 18	Aug. 10	Nov.
35	do.	38	30	400	NE.	do.	1904	17	Apr. 30	May 5	Apr. 23	Apr. 4	July 27	do.	Sept. 23	Sept. 10	Jan.
35	do.	38	30	400	NE.	do.	1905	18	Apr. 13	Apr. 22	Apr. 20	Mar. 29	July 18		Oct. 13	Sept. 1	
35	do.	38	30	400	NE.	do.	1906	19	Apr. 20	Apr. 25	May 10	Apr. 11	July 24	Sept. 1	Oct. 11	Aug. 15	Oct.
54	do.	39	0	1,000	NE.	Porous loam	1903	20	Apr. 9	Apr. 21	Apr. 5	Mar. 28	June 10	Sept. 25		Oct. 1	Dec.
54	do.	39	0	1,000	NE.	do.	1905	17	Apr. 18	Apr. 25	Apr. 19	Apr. 6	do.	do.			

[a] From cold storage.

TABLE IV. *Phenological records Apples* Continued.

YELLOW NEWTOWN. Synonym: *Albemarle Pippin.*

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
10	North Carolina	35 30	2,875	SW.	Clay loam	1905	8	....	....	Mar. 10	Mar. 28	July 5	Oct. 28	....	Nov. 20	Jan.
10f	do	35 30	4,500	SE.	Sandy loam	1902	12	May 1	May 6	Apr. 22	....	July 31	Oct. 25	Oct. 1	do	Dec.
47	Virginia	36 45	1,700	SE.	Black loam	1905	......	Apr. 15	May 1	May 1	....	....	....	do	Dec. 20	Apr.
51	do	37 10	2,900	SE.	Sandy loam	1905	25	May 5	....	Apr. 16	Apr. 10	....	Oct. 1	Oct. 20	Nov. 20	Do.
52	do	37 20	1,200	W.	Clay loam	1902	25	Apr. 10	Apr. 25	....	do	....	....	....	....	....
29	do	37 20	1,200	SE.	do	1903	20	do	Apr. 19	Apr. 6	Apr. 25	....	Oct. 15	....	Dec. –	Mar.
44	do	37 45	630	SW.	Loam	1904	15	Apr. 25	....	Apr. –	Apr. 10	June 15	....	....	....	....
42	do	37 45	800	SE.	Red clay	1903	20	Apr. 6	Apr. 15	Apr. 15	Apr. 25	....	Sept. 15	....	Jan. –	June.
44a	do	37 50	1,200	NW.	Porous loam	1907	26	Apr. 1	Apr. 20	Apr. –	....	....	Oct. 1	....	Dec. –	Apr.
45	do	37 50	1,200	....	....	1906	15	Apr. 19	Apr. 21	May 9	Apr. 14	....	....	Oct. 10	....	....
41	do	38 0	1,200	N.	Black loam	1903	19	....	....	Apr. 5	May 25	....	Sept. 18	Oct. 15	Mar. –	May.
54	do	39 0	1,000	NE.	Porous loam	1902	6	Apr. 24	Apr. 29	Apr. 14	Apr. 16	June 20	....	....	....	....

YELLOW TRANSPARENT.

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until
17	North Carolina	36 15	3,000	SE.	Clay loam	1904	8	Apr. 20	Apr. 25	May 3	Mar. 20	....	July 20	Oct. 11	June 10	
40	Virginia	37 10	2,400	None.	Porous loam	1907	8	Apr. 15	Apr. 20	Apr. 5	....	....	....	....	....	....
26	do	37 15	900	NW.	Sandy loam	1902	7	Apr. 21	Apr. 28	....	....	....	....	....	....	....
26	do	37 15	900	NW.	do	1903	8	Apr. 6	Apr. 11	....	....	June 1	June 10	....	June 10	July 15.
38	do	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 2	Apr. 18	Apr. 10	....	....	Sept. 14	....	....
38	do	37 15	2,170	NW.	do	1903	14	Apr. 15	Apr. 26	Apr. 5	Apr. 8	....	....	do	....	....
28	do	37 20	1,000	N.	Clay loam	1904	8	May 4	May 14	May 7	Apr. 17	....	July 20	....	July 20	Aug. 20.
28	do	37 20	1,000	N.	do	1906	10	Apr. 14	Apr. 16	Mar. 29	Apr. 2	July 2	....	Nov. 20	....	....
29	do	37 20	1,200	SE.	do	1903	6	Mar. 26	Apr. 8	Apr. 6	Apr. 10	....	....	....	....	....
27	do	37 30	1,000	NE.	do	1902	5	Apr. 21	Apr. 24	Mar. –	Apr. 8	....	July –	Nov. –	July 10	....
50	do	37 55	200	E.&W.	Sandy loam	1902	15	Apr. 17	Apr. 23	Apr. 9	Apr. 10	....	do	Oct. 30	July –	Aug. 30.
50	do	37 55	200	E.&W.	do	1903	16	Mar. 28	Apr. 2	....	Apr. 15	....	do	....	July 5	Aug. 1.
50	do	37 55	200	E.&W.	do	1904	17	Apr. 20	Apr. 25	Apr. 6	Apr. 25	....	July 10	Sept. 7	....	....
50	do	37 55	200	E.&W.	do	1905	18	Apr. 9	Apr. 14	Apr. 19	Apr. 14	....	do	Oct. 22	July 10	Aug. 1.
50	do	37 55	200	E.&W.	do	1906	19	Apr. 15	Apr. 25	May 11	Apr. 25	....	do	do	....	Do.
35	do	38 30	400	NE.	Red clay	1902	4	Apr. –	....	Apr. 15	Apr. 15	Aug. 24	....	....	....	....
35	do	38 30	400	NE.	do	1903	5	Apr. 7	Apr. 12	Apr. 5	Mar. 28	Aug. 1	June 29	Oct. 18	June 21	July 27.
35	do	38 30	400	NE.	do	1904	6	Apr. 27	May 6	Apr. 23	Apr. 7	July 12	July 18	Sept. 23	June 23	Aug. 6.
35	do	38 30	400	NE.	do	1905	7	....	....	Apr. 20	Apr. 2	July 22	....	Oct. 13	....	....

35	do	38	30	400	NE.	do	1906	8	Apr. 25	Apr. 29	May 10	Apr. 15	July 21		Oct. 11		
78	Delaware	38	45	50	None.	Sandy loam	1904	8	Apr. 29	May 4	Apr. 22	Apr. 12					
48	Virginia	38	45	375	SE.	Porous loam	1903	11	Apr. 8	Apr. 12	Apr. 5	Apr. 17	June 30	July 6	Oct. 25		July 25.
48	do	38	45	375	SE.	do	1905	13	Apr. 21	Apr. 23	Apr. 19	Apr. 21					
48	do	38	45	375	SE.	do	1906	25	Apr. 23	Apr. 26	May 11	May 1		June 30	Oct. 11	June 30	July 20.
48	do	38	45	375	SE.	do	1907	26	Apr. 27	Apr. 29	Apr. 20			July 20	Oct. 13		Aug. 15.
54	do	39	0	1,000	NE.	do	1904	10	May 3	May 9	do	Apr. 26					
54	do	39	0	1,000	NE.	do	1906	18	Apr. 26	Apr. 30	Apr. 24	Apr. 18	June 10	July 1		June 25	Aug.
76	Delaware	39	5	40	NE.	Sandy loam	1903	10	Apr. 11	Apr. 18	Apr. 6	Mar. 28	June 8	June 24			
76	do	39	5	40	NE.	do	1904	11	May 2	May 6	Apr. 21	Apr. 23	June 23	July 1	Oct. 28		
76	do	39	5	40	NE.	do	1905	12	Apr. 20	Apr. 24	Apr. 19	Apr. 3	June 9	June 30	Oct. 22		
74	do	39	10	70	None.	do	1902	10	Apr. 24	Apr. 27				June 25	Oct. 20	June 25	
73	do	39	10	100	N.	do	1902	10	Apr. 25	May 1		Apr. 13		do		July 1	
87	New Jersey	39	15	40	SW.	do	1902	10	Apr. 30	May 5		Apr. 24					
66	Maryland	39	20	75	N.	Clay loam	1903	6	Apr. 15	Apr. 24	Apr. 7	Apr. 9		July 6		July –	
65	do	39	20	75		Gravelly loam	1902	7	Apr. 23	Apr. 28		Apr. 1		June 28		June 28	
65	do	39	20	75		do	1903	8	Apr. 12	Apr. 22		do		June 26		June 20	
67	do	39	20	50	SE.	Sandy loam	1903	8	Apr. 9	Apr. 12	Apr. 6	Apr. 5		June 25	Oct. 26	July 5	
64	do	39	25	225	SE.	Stony loam	1905	15	Apr. 21	Apr. 26	Apr. 19	Apr. 19	Aug. 25	July 6	Oct. 19	June 25	
64	do	39	25	225	SE.	do	1906	16	Apr. 26	Apr. 30	May 10	Apr. 28	Aug. 30		Oct. 11		
60	do	39	35	75	SW.	Heavy loam	1902	10	May 1	May 4	May 28	Apr. 24	July 5	July 8	Nov. 15	July 8	
60	do	39	35	75	SW.	do	1903	11	Apr. 29	May 1	Apr. 20	Apr. 6			Nov. –		
60	do	39	35	75	SW.	do	1904	12	May 7	May 8	May 11	Apr. 30	June 30	July 25	Sept. 17		
79	New Jersey	39	35	90	NW.	Gravelly loam	1902		Apr. 24	Apr. 28	Apr. 15	Apr. 20		July 6	Nov. 15	July 6	
59	do	39	40	300		Clay loam	1902	10	Apr. 26	do	do	Apr. 15	July 1	July 15		July 1	
91	do	39	50					5	Apr. 30	May 1		Apr. 14	July 20	July 20		July 10	
82	do	39	55	50	W.	Sandy loam	1902	6	Apr. 27	May 3				July 15		do	
84	do	39	55	50	N.	Heavy loam	1902	25	Apr. 25	Apr. 30	Apr. 16	Apr. 20	Aug. 1	July 10	Oct. 10	July 20	
84	do	39	55	50	N.	do	1903	26	Apr. 18	Apr. 25	May 2	Apr. 1	July 25	July 15	Oct. –	July 15	
84	do	39	55	50	N.	do	1904	27	May 5	May 9		Apr. 25	July 10	July 4		July 4	
86	do	40	0	50	NW.	Loam	1904	20	do	May 7		do	July 15	July 1	Sept. 22	July 5	
86	do	40	0	50	NW.	do	1905	21	Apr. 29	May 4		May 8	July 1	July 15	Nov. –	July 1	
89	do	40	5	60	N.	Gravelly loam	1904		May 4	May 7	Apr. 24		June 1	Aug. 1	Oct. 10	July 10	
80	do	40	5	60	N.	do	1906	9			Apr. 6	Apr. 23	June 7	July 25		July 8	
80	do	40	5	60	N.	do	1907	12	May 5		Apr. 20	Apr. 8	June 28.	July 15		July 6	
81	do	40	10	75	None.	Heavy loam	1907	16	May 3	May 8		Apr. 24		July 23	Oct. 21	July 13	
95	do	40	10	40	N.	Sandy loam	1904	10	May 7	May 10				July 11	Sept. 22	July 4	
98	do	40	30	600	S.	Red shale	1905	14	May 1	May 7	Apr. 16	Apr. 29		July –	Oct. –		
99	do	40	35	40	NW.	Sandy loam	1907	10	May 10		May 12	May 4			Oct. 5		
88	do	40	50	500	E.	do	1907	10	May 8	May 12	Apr. 25	May 14		Aug. 1	Oct. 10	Aug. 1	
104	do	41	0	600	None.	Clay loam	1905	3	May 6	May 10	Apr. 24	Apr. 26	July 5	Aug. 12	Oct. 22	Aug. 12	
104	do	41	0	600	None.	do	1906	4	May 9	May 14	May 11	do	July 4	July 25	Oct. 12	Aug. 1	
104	do	41	0	600	None.	do	1907	5	May 15	May 20	May 12	Apr. 29	July 7	Aug. 6	Oct. 25	Aug. 19	
101	do	41	10	550	SE.	Gravelly loam	1904	11	May 6	May 15	Apr. 23	Apr. 28			Sept. 22		
103	do	41	15	400	SW.	Sandy loam	1904		May 10	do	May 5						

TABLE IV.—*Phenological records—Apples*—Continued.

YORK IMPERIAL. Synonym: *Johnson's Fine Winter.*

Observer's number.	State.	Approximate latitude.	Elevation (feet).	Slope.	Soil.	Year.	Age of tree (yrs.).	Date first bloom.	Date full bloom.	Date last spring frost.	Date leaf buds begin to open.	Date terminal buds begin to form.	Date picked (first picking).	Date first fall frost.	Date fit for use.	Keeps until—
11	North Carolina	35 25	1,990	SE.	Porous loam	1904	20	Apr. 30	May 5	Apr. 21	May 10	June 15	Sept. 15	Oct. 24	Oct. 20	Nov.
10	do	35 30	2,875	SW.	Clay loam	1903	7	Apr. 6	Apr. 16	Apr. 28	Apr. 4	July 15	Oct. 28	Oct. 25	Dec. 10	Feb.
10	do	35 30	2,875	SW.	do	1904	8	Apr. 15	Apr. 28	Apr. 26	Mar. 25	July 4	Oct. 15	Oct. 16	Nov. –	Dec.
10	do	35 30	2,875	SW.	do	1905	9	....	....	Mar. 10	Mar. 28	July 10	Oct. 25	....	Nov. 20	Feb.
12	do	35 30	3,500	SE.	Gravelly clay	1902	7	Apr. 22	Apr. 28	Apr. 15	Apr. 22	July 27	...do...	Oct. 5	Dec. 20	Do.
13	do	35 30	4,500	SE.	Sandy loam	1902	12	May 1	May 6	Apr. 22	....	July 31	Oct. 20	Oct. 1	...do...	Mar.
13	do	35 30	4,500	SE.	do	1903	14	May 5	May 18	Apr. 28	May 4	July 25	Oct. 15	Oct. 5	Dec. 1	Feb.
16	do	36 10	3,250	S.	Clay loam	1904	12	May 10	...do...	Apr. 21	Apr. 27	July 22	Oct. 10	Oct. 15	Dec. 15	Apr.
16	do	36 10	3,250	S.	do	1905	13	Apr. 20	May 1	May 16	Apr. 16	July 20	...do...	Oct. 20	...do...	Do.
47	Virginia	36 45	1,700	SE.	Black loam	1905	......	Apr. 15	...do...	May 1	....	....	Oct. 1	....	Nov. 20	Do.
33	do	37 0	5	None.	Sandy loam	1904	8	Apr. 23	Apr. 30	Apr. 20	Apr. 4	June 23	Sept. 5	Oct. 17	Oct. 10	Nov.
49	do	37 5	......	......	....	1907	11	Apr. 26	May 7	...do...	May 5	....	Oct. 6	Oct. 15	Sept. 25	Apr.
40	do	37 10	2,460	None.	Clay loam	1907	8	Apr. 12	Apr. 30	Apr. 8	....	....	....	....	....	....
39	do	37 10	2,000	NW.	Dark loam	1902	10	Apr. 26	May 1	Apr. 18	Apr. 20	....	Oct. 10	Sept. 10	Jan. 20	Apr.
46	do	37 15	500	S.	Sandy loam	1903	16	Apr. 2	Apr. 6	....	....	....	....	....	Oct. 1	Mar.
38	do	37 15	2,170	NW.	Limestone clay	1902	13	Apr. 28	May 3	Apr. 18	Apr. 11	....	Sept. 25	Sept. 14	....	....
24	do	37 20	1,000	S.	Red clay	1903	......	....	....	Apr. 5	....	....	Oct. 30	Oct. 30	....	....
25	do	37 20	1,000	SE.	do	1905	18	Apr. 25	May 5	Apr. 15	Apr. 25	July 20	Oct. 20	Oct. 20	Nov. 15	Apr.
31	do	37 25	1,400	NW.	Gravelly loam	1902	6	Apr. 21	Apr. 24	Apr. 8	Apr. 21	July –	Sept. 25	....	...do...	....
44	do	37 45	630	SW.	Loam	1904	12	Apr. 24	....	Apr. –	Apr. 10	June 15	....	....	....	....
42	do	37 45	800	SE.	Clay loam	1903	20	Mar. 24	Apr. 15	Apr. 15	Apr. 25	....	Sept. 15	....	Dec. 15	June.
45	do	37 50	....	....	....	1906	20	....	Apr. 22	May 9	....	....	....	Oct. 10	....	....
50	do	37 55	200	E.&W.	Sandy loam	1903	16	Mar. 30	Apr. 4	....	Apr. 5	....	Oct. –	....	Oct. 20	Mar.
50	do	37 55	200	E.&W.	do	1904	17	Apr. 20	Apr. 25	Apr. 6	Apr. 25	....	Nov. 1	Sept. 7	....	....
50	do	37 55	200	E.&W.	do	1905	18	Apr. 10	Apr. 15	Apr. 19	Apr. 15	....	Oct. 1	Oct. 22	Oct. 1	Dec.
50	do	37 55	200	E.&W.	do	1906	19	Apr. 15	Apr. 25	May 11	Apr. 25	....	Oct. 20	....	Oct. 30	Do.
41	do	38 0	1,200	N.	Black loam	1903	19	....	....	Apr. 5	Mar. 26	....	Oct. 2	Oct. 15	Jan. 15	Mar.
19	do	38 5	900	S.	Red clay	1905	18	Apr. 15	Apr. 23	Apr. 19	Apr. 1	....	Sept. 1	Oct. 7	Sept. 1	....
22	do	38 10	1,200	NE.	Gravelly loam	1907	20	Apr. 20	...do...	May 22	Mar. 29	....	Oct. 15	Oct. 9	Jan. 15	Mar.
23	do	38 10	1,400	NE.	do	1907	9	Apr. 23	May 1	May 18	Apr. 1	July 20	Oct. 8	Oct. 13	Dec. –	May.
53	do	38 25	1,400	W.	do	1902	16	Apr. 26	...do...	....	Apr. 15	....	Oct. 1	....	....	....
53	do	38 25	1,400	W.	do	1903	17	Apr. 13	Apr. 22	....	Apr. 10	....	Oct. –	....	Dec. –	Feb.
53	do	38 25	1,400	W.	do	1905	19	Apr. 20	Apr. 28	Apr. 24	Apr. 11	....	Oct. –	Oct. –	Oct. –	Do.
53	do	38 25	1,400	W.	do	1906	20	Apr. 25	May 1	May 11	Apr. 15	....	Sept. 25	....	....	....
35	do	38 30	400	NE.	Red clay	1902	15	Apr. 24	Apr. 27	Apr. 15	...do...	Aug. 20	Oct. 15	Oct. 22	Oct. 1	Apr.
35	do	38 30	400	NE.	do	1903	16	Apr. 12	Apr. 22	Apr. 5	Apr. 2	Aug. 4	Oct. 1	Oct. 18	....	Do.
35	do	38 30	400	NE.	do	1904	17	Apr. 30	May 6	Apr. 23	Apr. 8	July 29	Sept. 26	Sept. 23	Sept. 1	Do.

35	....do..............	38	30	400	NE.	.....do............	1905	18	Apr. 19	Apr. 26	Apr. 20	Apr. 3	July 18	....	Oct. 13	....	....
35	....do..............	38	30	400	NE.	.....do............	1906	19	Apr. 22	Apr. 28	May 11	Apr. 11	July 26	....	Oct. 11	....	May.
48	....do..............	38	45	375	SE.	Porous loam	1903	15	Apr. 8	Apr. 12	Apr. 5	Apr. 15	July 1	Sept. 15	Oct. 25	....	Do.
48	....do..............	38	45	375	SE.	.....do............	1906	33	Apr. 27	Apr. 29	May 11	Apr. 30	....	....	Oct. 11	....	Mar.
55	....do..............	39	0	600	....	Sandy loam.......	1907	14	May 1	May 9	May 9	Apr. 15	....	Oct. 10	Oct. 10	Feb. –	Apr.
54	....do..............	39	0	1,000	NE.	Porous loam	1902	14	Apr. 24	Apr. 28	Apr. 14	Apr. 18	June 15	Sept. 25	....	Sept. 25	Late.
54	....do..............	39	0	1,000	NE.	.....do............	1903	15	Apr. 10	Apr. 22	Apr. 5	Apr. 2	June 10	Sept. 30	....	Dec. 1	June.
54	....do..............	39	0	1,000	NE.	.....do............	1904	16	May 4	May 10	Apr. 20	Apr. 27	...do.....	...do.....	....	Oct. –	May.
54	....do..............	39	0	1,000	NE.	.....do............	1905	17	Apr. 22	Apr. 28	Apr. 19	Apr. 10	...do.....	Oct. 1	....	....	....
54	....do..............	39	0	1,000	NE.	.....do............	1906	18	Apr. 25	May 1	May 8	Apr. 19	...do.....	...do.....	....	Oct. 1	Apr.
54	....do..............	39	0	1,000	NE.	.....do............	1907	19	Apr. 22	Apr. 27	Apr. 23	Apr. 3	June 15	...do.....	....	Dec. –	June.
32	....do..............	39	10	500	NW.	Clay loam.........	1905	11	Apr. 25	...do.....	Apr. 18	Apr. 7	June 18	Oct. 4	....	Dec. 1	Mar.
32	....do..............	39	10	500	NW.	.....do............	1906	12	Apr. 30	May 4	Apr. 25	Apr. 20	June 15	....	Oct. 15	....	....
37	....do..............	39	10	600	NW.	.....do............	1903	17	Apr. 20	Apr. 25	....	....	....	....	....	....	....
72	Delaware...........	39	10	70	None.	Sandy loam.......	1902	7	Apr. 24	Apr. 27	....	....	....	Oct. 30	Oct. 20	Dec. 1	Apr.
68	Maryland...........	39	10	550	S.	Clay loam.........	1906	9	Apr. 20	May 3	May 10	Apr. 19	....	Oct. 1	Oct. 12	Nov. 15	Jan.
65	....do..............	39	20	75	....	Gravelly loam.....	1902	6	Apr. 26	Apr. 29	....	Apr. 9	....	....	....	....	....
65	....do..............	39	20	75	....	.....do............	1903	7	Apr. 20	....	....	Apr. 2	....	....	....	....	....
64	....do..............	39	25	225	S.	Porous loam	1907	7	May 5	May 10	May 5	May 1	....	....	Oct. 17	....	....
63	....do..............	39	30	150	N.	Clay loam.........	1907	20	May 1	May 6	May 12	Apr. 24	Aug. 6	Oct. 14	Oct. 15	....	Apr.
58	....do..............	39	35	300	S.	Limestone loam...	1906	20	...do.....	May 5	May 10	Apr. 25	....	Oct. 1	Oct. 12	Nov. 1	May.
58	....do..............	39	35	300	S.	.....do............	1907	21	May 4	May 9	May 12	Apr. 28	....	Oct. 25	Oct. 15	...do.....	Do.
62	....do..............	39	35	500	E.	Loam..............	1905	40	Apr. 28	May 6	....	....	....	Oct. 10	....	Dec. 1	Do.
60	....do..............	39	35	75	SW.	Heavy loam.......	1902	15	Apr. 27	May 2	May 28	Apr. 23	July 10	Oct. 5	Nov. 15	Sept. 1	Late.
60	....do..............	39	35	75	SW.	.....do............	1903	16	Apr. 29	...do.....	Apr. 20	Apr. 6	July 20	....	Nov. –	....	....
60	....do..............	39	35	75	SW.	.....do............	1904	17	May 9	May 12	May 11	Apr. 30	June 30	Oct. 5	Sept. 17	....	Late.
69	....do..............	39	35	125	SW.	Sandy loam.......	1902	35	Apr. 26	Apr. 28	Apr. 20	Apr. 22	July 12	Sept. 12	Nov. 15	Sept. 1	Do.
69	....do..............	39	35	125	SW.	.....do............	1903	36	Apr. 23	...do.....	...do.....	Apr. 24	July 9	Oct. 3	Nov. –	....	Mar.
69	....do..............	39	35	125	SW.	.....do............	1904	37	May 2	May 9	Apr. 21	Apr. 29	July 5	Oct. 8	Sept. 17	....	Late.
90	New Jersey.........	39	45	125	SW.	Gravelly loam.....	1907	10	May 4	May 10	...do.....	....	....	....	....	....	....
82	....do..............	39	55	50	W.	Sandy loam.......	1902	6	Apr. 25	May 2	....	....	....	Sept. 20	....	Sept. 20	Dec.
84	....do..............	39	55	50	N.	Heavy loam.......	1902	35	Apr. 27	May 1	Apr. 16	Apr. 20	Sept. 15	Oct. 1	Oct. 10	Nov. 20	Apr.
84	....do..............	39	55	50	N.	.....do............	1904	37	May 7	May 11	....	Apr. 27	Aug. 10	...do.....	....	Dec. 1	Mar.
86	....do..............	40	0	50	NW.	Loam..............	1904	20	May 5	May 8	....	Apr. 28	July 25	...do.....	Sept. 22	Oct. –	Late.
81	....do..............	40	10	75	None.	Heavy loam.......	1907	12	...do.....	May 11	....	Apr. 25	....	Oct. 7	Oct. 21	....	Do.
96	....do..............	40	15	90	N.& S.	Clay loam.........	1904	10	May 10	May 16	....	May 7	....	Oct. 10	Sept. 17	Oct. 10	....
96	....do..............	40	15	90	N.& S.	.....do............	1905	11	May 4	May 10	....	Apr. 25	....	Oct. 13	Oct. 18	Feb. –	Mar.
94	....do..............	40	20	140	S.	Sandy loam.......	1903	37	Apr. 28	May 1	May –	Apr. 9	June 13	Oct. 10	Oct. –	Oct. –	Do.
94	....do..............	40	20	140	S.	.....do............	1904	38	May 6	May 11	....	Apr. 30	July 16	Oct. 1	Sept. 20	...do.....	Do.
98	....do..............	40	30	400	S.	Red shale.........	1905	14	....	May 8	Apr. 16	Apr. 26	....	Sept. –	Oct. –	....	Do.
[illegible]	....do..............	40	35	40	NW.	Sandy loam.......	1907	12	May 9	....	May 12	May 1	Sept. 15	Oct. 15	Oct. 5	Oct. –	Apr.

PLATES.

DESCRIPTION OF PLATES.

Plate I. (*Frontispiece.*) A well-kept Yellow Transparent orchard about 10 years old. Good cultivation has been given and the trees have made an excellent growth.

Plate II. Wagons and packages used in handling summer apples. Fig. 1.—Wagon loaded with half-bushel baskets of summer apples for the Philadelphia market. This load consists of 149 baskets. The wagon is a common type used in New Jersey in the vicinity of Philadelphia for hauling apples, tomatoes, and other truck to market. Fig. 2.—Wagon loaded with seventy-three ⅞-bushel baskets of summer apples ready for hauling to the railroad station. The wagon is a common type used in Delaware for this purpose. The manner of loading the baskets on the wagon is also shown.

Plate III. Packing-house views. Fig. 1.—Exterior view of a packing house in Delaware. There are four doors, one on either side. Each door is numbered to facilitate in giving directions in regard to receiving and discharging fruit. A truck used in hauling fruit from the orchard to the packing house is also shown. Fig. 2.—Interior view of a packing house in Delaware showing a common method of handling the fruit in grading and packing summer apples. Covers are attached to the baskets before they leave the packing house.

Plate IV. Typical summer-apple orchards. Fig. 1.—A Maiden Blush orchard in New Jersey, about 30 years old. The props under the trees are suggestive of the productiveness of this variety in this section. The orchard receives thorough cultivation and spraying. Fig. 2.—A Red Astrachan orchard in Delaware, about 25 years old. It has been well maintained. The trees are 36 feet apart. The branches nearly interlock in both directions.

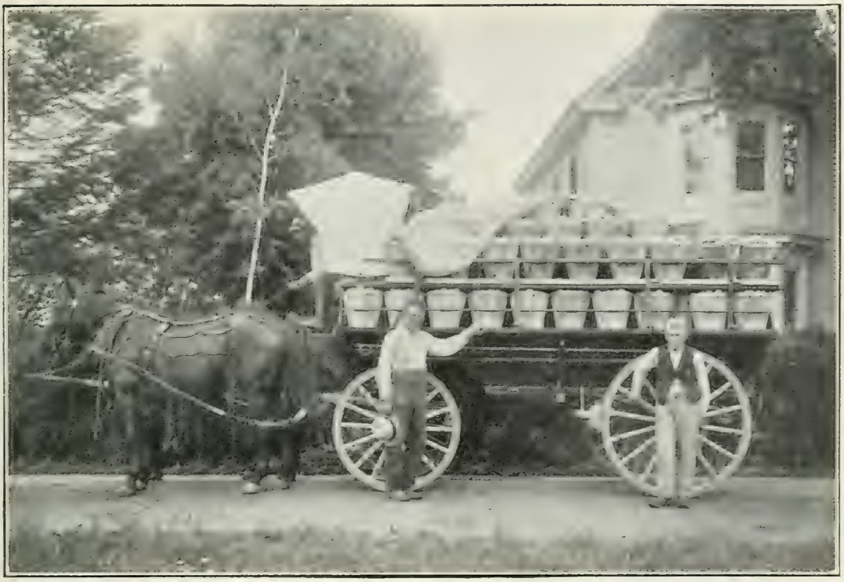

FIG. 1.—WAGON LOADED WITH HALF-BUSHEL BASKETS OF SUMMER APPLES GROWN IN NEW JERSEY FOR THE PHILADELPHIA MARKET.

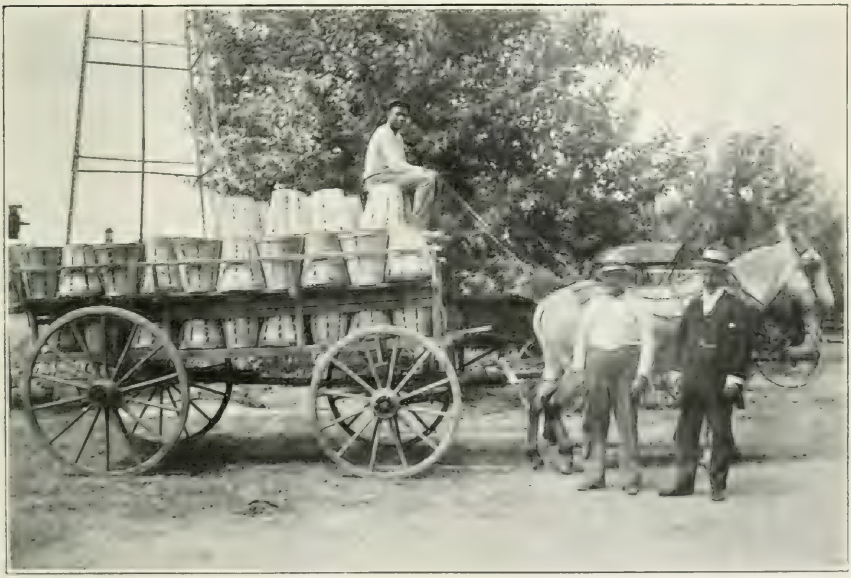

FIG. 2.—WAGON LOADED WITH SEVEN-EIGHTHS-BUSHEL BASKETS OF SUMMER APPLES GROWN IN DELAWARE, READY TO BE HAULED TO THE SHIPPING STATION.

WAGON AND PACKAGES USED IN HANDLING SUMMER APPLES.

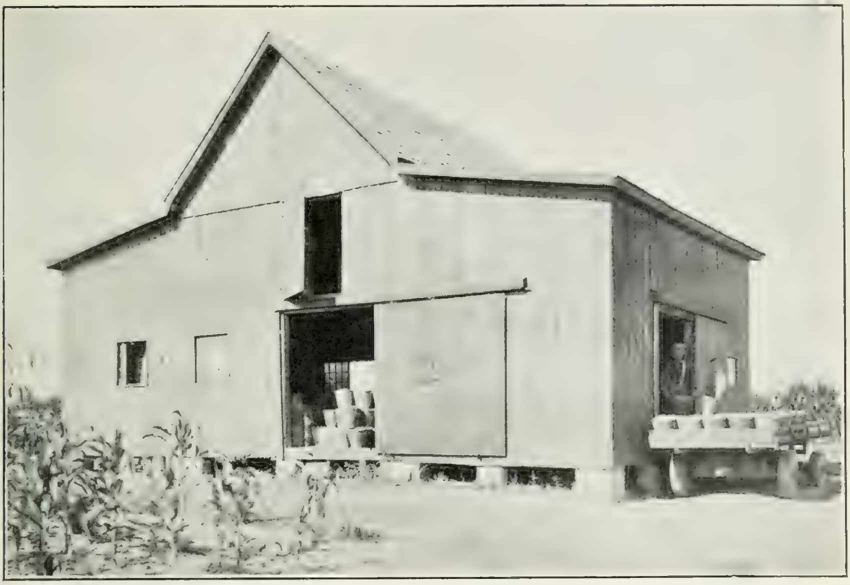

FIG. 1.—EXTERIOR VIEW OF A PACKING HOUSE.

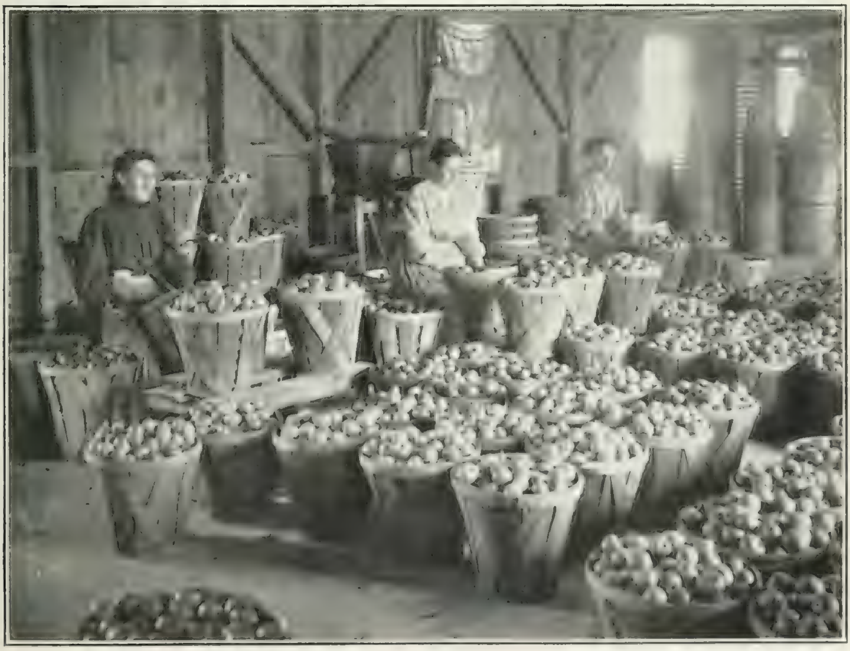

FIG. 2.—INTERIOR VIEW OF A PACKING HOUSE, SHOWING A COMMON METHOD OF HANDLING THE FRUIT IN GRADING AND PACKING SUMMER APPLES.

PACKING-HOUSE VIEWS IN DELAWARE.

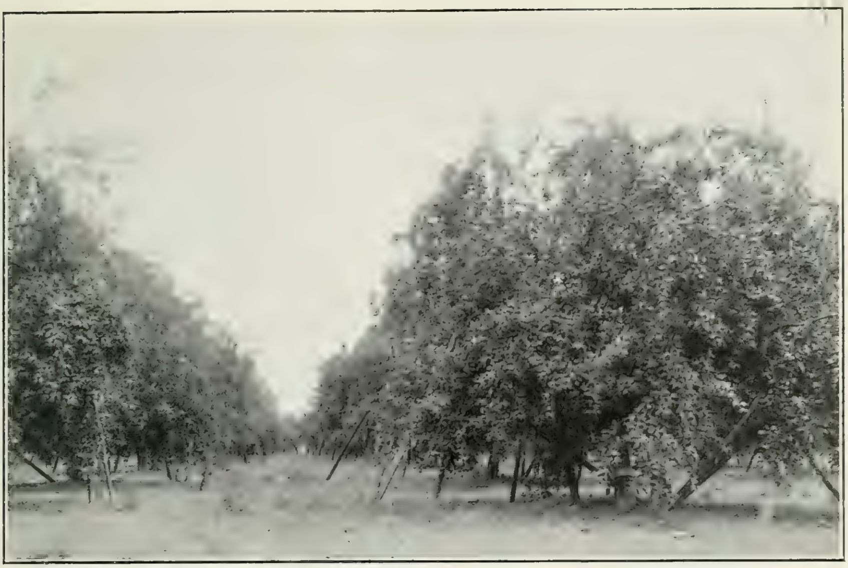

FIG. 1.—A MAIDEN BLUSH ORCHARD IN NEW JERSEY, ABOUT 30 YEARS OLD.

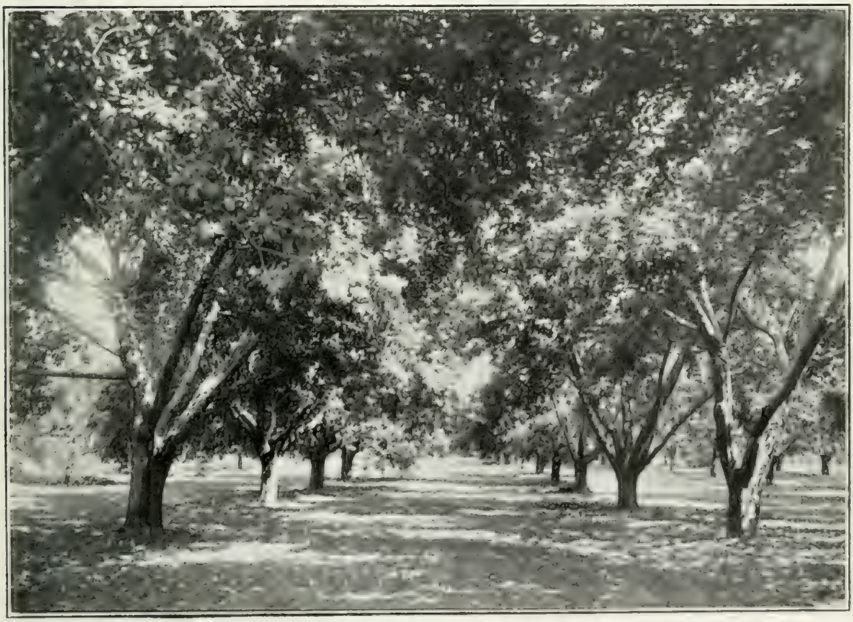

FIG. 2.—A RED ASTRACHAN ORCHARD IN DELAWARE, ABOUT 25 YEARS OLD.

TYPICAL SUMMER-APPLE ORCHARDS.

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[Synonyms of apples are distinguished from the leading varietal names by the use of italic type.]

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 195.

B. T. GALLOWAY, *Chief of Bureau.*

THE PRODUCTION OF VOLATILE OILS AND PERFUMERY PLANTS IN THE UNITED STATES.

BY

FRANK RABAK,

Chemical Biologist, Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

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Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 26, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 195 of the special series of this Bureau a manuscript by Mr. Frank Rabak, Chemical Biologist, entitled "The Production of Volatile Oils and Perfumery Plants in the United States," submitted by Dr. R. H. True, Physiologist in Charge of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

There is a steady demand for information concerning plants yielding materials used in the manufacture of perfumery products; also concerning the processes and apparatus required to utilize these oil-bearing plants. This line of agricultural work has not yet reached any marked development outside of the peppermint industry in Michigan, New York, and Indiana, but the outlook for a further growth of this branch of special agriculture seems worth consideration. Much experimental work will be required to determine the most favorable locations for operation, and practical experience in handling the crops and the special apparatus needed in utilizing them must be accumulated. However, the economic significance of this class of products seems likely to justify the efforts required.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—603.

THE PRODUCTION OF VOLATILE OILS AND PERFUMERY PLANTS IN THE UNITED STATES.

INTRODUCTION.

The use of aromatics and perfumery dates back to the early ages when spices, balsams, asafetida, and other resinous exudations, many of which possess agreeable odors, were used for the purpose of scenting. The peculiar, agreeable aromas emanating from plants growing in their native habitats may be supposed to have early aroused the attention and admiration of the primitive peoples, although it may not have been known in what forms plants and flowers possessed their aromas. Before the art of distillation was known, the ancient peoples used the odoriferous plants and spices in their dried forms for their agreeable odors. Gradually, however, the development of special utensils for other domestic purposes may have resulted in the discovery of methods for the separation of odors from plants and plant products.

The use of distilling apparatus by the ancients in their endeavor to solve the problem of the transmutation of the elements and in other researches requiring the separation of volatile from nonvolatile substances antedates its use for the production of essential oils and perfumes, but it was probably learned at an early date that the odors present in plants and plant exudations were capable of separation because of their greater volatility when compared with the other constituents present. The first mention in ancient Greek writings of the separation of an odor from a crude substance is that of the oil of cedar, which was separated from the oleoresin by means of the crudest form of apparatus. This consisted of an open earthen kettle in which the oleoresin was boiled with water, the vapors of steam and oil being collected in layers of wool so placed that the steam from the kettle passed through the wool, which served as a condenser and retained the oil and water. Gradually this apparatus was transformed until it consisted of two definitely related parts, the kettle, or body of the still, and the removable head, which, besides closing the kettle, also acted as a condensing device on account of its exposure of a large surface to the air. Further improvements were made from

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time to time, until the apparatus came to consist of a still body with a detachable head, to admit of the introduction of the material, and of a condensing worm or tube surrounded by flowing cold water. The highly efficient modern still embodies in a more elaborated adaptation the essential principles of this crude apparatus.

Along with the development of the necessary apparatus there have grown up in different parts of the world many large and small industries founded on volatile-oil production. From the small stills formerly used in making essences or spirits for use in the home for medicinal, condimental, or perfumery purposes from herbs gathered wild or grown in the garden, there have come the extensive perfumery industries of southeastern France, the attar-of-rose industry in Bulgaria, the peppermint and turpentine industries in the United States, and the other many and varied phases of the great industry of volatile-oil production.

The present centers of activity in this branch of manufacture have become established where they exist through a favorable combination of conditions, including the adaptation of soil and climatic conditions to the needs of the plants concerned and suitable labor conditions. In southwestern France a general perfumery industry of great importance, based on the production of lavender, cassie, rose, violet, and other perfumery plants, has grown up. The attar of roses from Bulgaria and Turkey, the rose-geranium oils from Algeria, Reunion, and other French colonies, the lavender and other essential oils from England, and the citrus oils from Italy, as well as the lemon-grass, citronella, vetiver, and other volatile-oil and perfume-producing products from India, may be mentioned as important industrial products. In the United States and in Japan the production of peppermint oil and its products constitutes an important industry. In many instances introduced plants are used; in others, native species, usually brought under cultivation, form the basis of production.

The growth of the volatile-oil industry has been most rapid in late years in Germany and France, due in part to the opening up of remunerative lines of work by pioneering scientific workers and in part to the greater demand for these products by the manufacturers of those countries. Although volatile oils find much use in a medicinal way, the greatest demands come from the makers of perfumeries and of flavors. As a result of scientific research along the lines of perfume chemistry, not only has a great field for commercial activity been discovered but scientific knowledge itself has been greatly enlarged. This mutually helpful relation between science and commerce has been conspicuously developed in France and Germany, but to only a relatively slight extent in this country. In view of the increasing importance of this class of products to American commerce, it seems highly advisable that steps be taken to investigate the possibilities of our country in this direction. With our great range of latitude and variety of climate and soil, the conditions naturally favorable to the production of such oils and perfumes should be available. Other questions, such as labor and transportation facilities, must be considered. It is probable that by careful, scientific study of the situation the way may be opened for the development of somewhat extensive industries based on the growing and manufacturing in this country of volatile-oil products now either imported or neglected. These industries are already represented by the peppermint, spearmint, and wormwood products grown in New York, Michigan, Indiana, Wisconsin, and other States of the upper Mississippi Valley.

AROMA OF PLANTS.

NATURE OF ODORS.

Of the countless numbers of plants in the vegetable kingdom, a large percentage possesses peculiar aromatic odors, by means of which the plants may ofttimes be characterized. The substances which impart these peculiar odors to plants consist of mixtures of compounds oily in character and of a volatile nature; hence the designation "volatile oils."

It may be generally stated that all plants which in the growing condition give off a pronounced odor or which produce this odor when the leaves or flowers are rubbed between the fingers contain an essential oil. However, this must not be construed to mean that all volatile oils must necessarily be derived from plants which possess an odor, there being plants which do not possess the oil pre-formed in the tissues, but which through the interaction of constituents in the plant under proper conditions yield a volatile oil. A common example of this class of plants or plant products is the bitter almond, which yields the bitter-almond oil of commerce by maceration of the ground kernels with water, the oil formation taking place during maceration.

The aroma of plants is not necessarily due to volatile oils, there being other odor-bearing substances which, while distinctly aromatic, are not of an oily character. Reference is here made to plants and plant products which, while not possessing any odor during the growing period, develop very fragrant odors after harvesting and drying. An example of this class is the vanilla bean of commerce, which in a green condition is odorless but which when properly cured develops the characteristic fragrant vanilla odor. In this case, according to Lecomte,[a] a glucosidal body in the plant, coniferin, is hydrolized during the curing process by plant enzymes or ferments to the compound coniferyl alcohol, which in turn is oxidized by oxydase to vanillin. In this case a characteristic odor is perceptible, yet no volatile oil can be separated from the plant. A fuller discussion of this class of substances will follow.

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[a] Lecomte, Henri. Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences, vol. 133, 1901, p. 745.

With only a few exceptions it may be stated that volatile oils exist in the tissues of a plant as minute globules, sometimes inclosed in cells but in some instances in enlarged cavities so conspicuous as to be seen without the aid of a lens or a microscope. By a careful examination of the leaf of a peppermint plant, especially at the time of blossoming, tiny glistening particles of oil are clearly discernible. The close scrutiny of the peel of a lemon or an orange discloses to view small, circular oil glands under the epidermis, imparting to it much of the characteristic roughened appearance. Such seeds as cloves, fennel, and anise contain oil passages directly below the epidermis surrounding the endosperm or embryo of the seeds.

The volatile oils in plants do not represent simple substances but are complex mixtures of numerous aromatic compounds which possess a definite chemical composition. However complex the composition of an oil may be, usually one constituent seems to impart the characteristic odor and stands out conspicuously. Generally this constituent attracts attention as the odor bearer of the plant or oil.

The substances which supply the aroma to plants or to essential oils may be resolved by chemical classification into several groups of organic compounds, namely, hydrocarbons, acids, alcohols, esters, aldehydes, ketones, oxids, phenols, and sulphur compounds.

Volatile oils with but few exceptions contain constituents which belong to two or more of the above-mentioned groups of organic compounds. Although each of the groups may contribute to the complex odor of a plant or of a volatile oil, usually compounds exist in the oil which seem to the observer to be especially agreeable and fragrant. The bearers of these pleasant odors which are so apparent even in complex mixtures are for the most part either ester-like or alcoholic in character. It is not unusual, however, that aldehydes, ketones, or phenols play the rôle of odor bearers in a few oils or plants, as, for example, the principal odorous constituent of lemon oil, which is the aldehyde citral, while the pronounced odor of pennyroyal oil is chiefly due to the ketone pulegone. The strongly aromatic odor of thyme is attributed to the phenol called thymol, while sulphur compounds are largely responsible for the aroma of the mustard oils.

Thus it may be perceived that while esters and alcohols impart agreeableness to the majority of oils, there are exceptions, as already stated. Such oils as peppermint, lavender, wormwood, rose, geranium, ylang-ylang, orange flower, and numerous others owe their fragrance to alcohol or ester compounds, or to both, since these compounds are usually found accompanying one another in the oils. Owing to their particularly agreeable fragrance, the esters and the alcohols form a class of the so-called desirable constituents.

Esters represent a group of constituents which are formed by the interaction of alcohols and plant acids (esterification), an ester resulting by the elimination of water in the reaction. Almost invariably these esters possess a pleasant odor and convey the characteristic mellowness and fragrance to many of the essential oils from plants. Indeed, a number of oils are valued according to the percentage of esters which they contain. The largest number of pleasant-smelling esters usually occur in oils as formates, acetates, or butyrates, the acetic-acid esters prevailing. The oil of lavender flowers, for instance, owes its agreeable aroma to the acetic-acid ester of the alcohol linalool or to linalyl acetate. The oil is valued according to the percentage of linalyl acetate which it contains, although the free alcohol linalool also exists in the oil. In this connection it may be mentioned that the ester menthyl acetate imparts fragrance to peppermint oil, menthol being also an important constituent in this case.

Another striking example of an ester compound as the odor bearer of an oil is the methyl ester of anthranilic acid, which carries the odor of orange flowers. Further examples are not necessary to emphasize the importance of esters and alcohols in determining the aromatic value of oils or plants.

In view of the fact that certain constituents may be classed as odor bearers, the desirability of these constituents in volatile oils being evident, attention should be given to the possibility of increasing this class of substances by proper conditions of climate and cultivation.

LOCALIZATION OF ODORS.

Volatile oils, although found in all parts of plants, are localized more or less generally in certain portions. The leaves, possibly on account of their extensive area, often carry a large proportion of oil. In many plants, indeed, the leaves serve as the chief source of the oil. Mention may be made here of the oils obtained from leaves of such plants as the eucalyptus, bay, wintergreen, pine, lemon grass, citronella, and ginger grass. On the other hand, in some plants the oil is obtained principally from other parts, the leaves possessing little or no odor, as in the oil-yielding roses.

The flowering tops of aromatic plants as a rule yield oils of rich aroma, excelling the oils produced from any other portion of the plant. The exquisite bouquet of such oils as rose, lavender, cassie, orange flower, and ylang-ylang is well known, all of these oils being obtained from the flowers or flowering tops.

The fruit oils occupy a position of no little importance, representing an industry by themselves. The principal oils from the citrus fruits are obtained from the lemon, sweet orange, bitter orange (petit grain), and bergamot. In all of the above fruits the essential oil is contained in the peel of the fruit from which it is obtained.

Many of the various seed oils are very important commercially, being employed largely as perfumes and medicinal agents. Among the seed oils derived from the order Umbelliferæ (parsnip family) which possess especial value may be mentioned caraway, anise, fennel, and coriander. Other seeds yielding oils of commercial import are cardamom, American wormseed, mustard, bitter almond, peach, and apricot seeds.

In addition to the above and playing an important rôle in volatile-oil production are the bark and wood oils, the former being represented by such oils as sassafras, canella, and cinnamon. The wood oils comprise such oils as sandalwood, copaiba, and cedar, while from the woods indirectly are obtained several essential oils of value, namely, oils from oleoresins, as turpentine, copaiba, elemi, California turpentine (*Pinus sabiniana*), and Oregon balsam oil.

There are comparatively few root oils, the chief examples being valerian, snakeroot, and sassafras oils.

The aerial portion of the plant serves possibly more extensively for the extraction of volatile oils than any other of the plant parts mentioned. Peppermint, spearmint, and wormwood, from which oils are now produced commercially in this country, are typical instances.

DEVELOPMENT OF AROMA.

The development of the aroma in a plant is conditioned by the interaction of several important factors. It is generally accepted that a close relationship exists between the growth of the plant and climatic factors, such as heat, light, and moisture, and it seems clear also that these conditions play an important part in the formation of the aroma and materially influence its quality. The effect of climate upon the quality of the aroma is clearly shown by the varying fragrance of the oils produced by plants of the same species when they are grown in sections having a wide diversity of climatic conditions. Continuous sunshine, which may be a factor in the development of fragrance in one plant, may possibly exert a reverse action upon another in which the formation of the chief odoriferous constituents is not directly favored by the action of light. Usually, however, sunshine is a favorable agent for the production of delicate aromas, while, on the other hand, cloudiness or darkness has a tendency to lower the production of aromatic substances by the plant.

An abundance of moisture is required for the growth of certain plants and also for the development of aroma. This is especially true of plants whose habitat may be aquatic or subaquatic; in this case dryness becomes a direct hindrance to growth and likewise lessens the activity of the metabolic processes taking place within the organism.

On the other hand, many plants are especial lovers of dryness, particularly such as inhabit the western arid tracts and deserts. These excessively dry regions are not devoid of plant life; neither are they wanting in plants possessing odors. The sages are excellent examples of sturdy growers on dry lands, and many are decidedly aromatic, producing oils of excellent quality.

In both of the above extreme cases, coupled with the dryness or moisture, an abundance of sunshine is usually conducive to the formation of volatile oils in plant organs.

A typical example may be mentioned in the case of lavender. This highly fragrant oil is derived from the plant *Lavandula vera*, which grows for the most part in France and England and is much influenced by such factors as soil, dryness, moisture, altitude, and sunshine. Oils which possess the highest percentage of the odor bearer, linalyl acetate, are usually produced from plants grown on mountain slopes.

Lamothe[a] states that the finest grades of lavender plants of the Dromé region are grown at the highest altitudes (2,500 feet) in the mountain districts. Plants grown on the lowlands of these mountains have been found to be decidedly inferior. Most light soils are well suited to the growth of lavender, but those of a heavy or soggy nature should be avoided.

The lavender produced in the Mitcham district of England is generally considered to have the most agreeable fragrance. In England the conditions are decidedly different from those occurring in France, both with respect to soil and altitude. A chalky soil seems to be best adapted to the growth of lavender in the Mitcham district. The plant is, however, also grown profitably in the vicinity of Bournemouth, Dorsetshire, where the soil consists of sand and clay, with more or less peaty humus.[b] Fungous growths, it is stated, harm lavender where the drainage is not perfect. An abundance of humidity and sunshine is also considered necessary by the English growers.

Although it is generally conceded that the English lavender oil is the most fragrant, this property is attributed by Gildemeister, Hoffmann, and Kremers[c] to the invariably low ester content of the oil.

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[a] Lamothe, M. L. Bul. Roure-Bertrand Fils., October, 1908, p. 33.

[b] Pharmaceutical Journal, vol. 83, 1909, p. 532.

[c] Gildemeister, Eduard, Hoffmann, Friedrich, and Kremers, Edward. The Volatile Oils, p. 606.

and their findings are further substantiated by Kebler[a] and by Parry.[b]

In the United States the cultivation of lavender has not advanced to any extent. However, in view of the fact that certain regions of the United States possess climate, soil, and other factors practically similar to those of the lavender-producing regions of France and of England, it does not necessarily follow that lavender may not be grown profitably in America.

The nature of the soil through its physical and chemical properties offers an important variable condition likely to affect the metabolism of the plant, and consequently the constituents elaborated by it. Experiments upon peppermint by Charabot and Hebert[c] seem to indicate that soils supplied with commercial fertilizers produce plants yielding oils superior in esters or odor-bearing compounds, the esterification of menthol in the plant seeming to be favored. Peppermint grown by the writer upon a soil rich in organic matter, a black loam, produced an oil noticeably richer in menthyl acetate than peppermint grown upon a clay loam. The existing conditions of climate were possibly also instrumental in bringing about this result.

Seasonal changes have also a marked effect not only upon the quality but also upon the quantity of oil produced by a plant. A plant distilled at its flowering period during one season may produce a certain yield of oil of certain quality, and in the following season, which may be entirely different, it may produce a much higher or lower yield of oil either superior or inferior in quality.

The agents already enumerated are instrumental in bringing about certain chemical changes in the composition of the oil in the cells or tissues of the living plants which contain the oil already formed. There is, however, another group of plants which, though not possessing the oil already formed in the plant tissues, do possess certain basal constituents from which the volatile oil is formed. These constituents usually belong to a class of plant constituents known as glucosids, which break down by hydrolysis into a sugar, generally glucose, and some other compound. The "other compound" which is formed by this hydrolysis in the case of some glucosids is volatile and constitutes the volatile oil from the plant.

Very common examples of plants with glucosidal bodies which yield a volatile oil are wintergreen and sweet birch. The leaves of the wintergreen and bark of the sweet birch contain the glucosid gaultherin, which under proper conditions of hydrolysis yields methyl salicylate and glucose. Methyl salicylate in this instance represents the volatile oil of wintergreen. In order to effect this hydrolysis of the glucosid in wintergreen or sweet birch, the material is simply macerated with water. A reaction immediately begins, assisted by the plant ferments, which act as catalysing agents, with the formation of the volatile methyl salicylate and glucose, as follows:

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[a] Kebler, L. F. American Journal of Pharmacy, 1900, p. 223.

[b] Parry, E. L. Chemist and Druggist, 1902, p. 168.

[c] Charabot, A., and Hebert, A. Bulletin du Jardin Colonial, vol. 27, 1902, 3d ser., pp. 224 and 914.

$$\frac{C_{14}H_{18}O_8}{\text{gaultherin}}+H_2O=\frac{C_6H_4(OH)COOCH_3}{\text{methyl salicylate}}+\frac{C_6H_{12}O_6}{\text{glucose}}.$$

If after the reaction is complete the fermented material is put into a distilling apparatus, the volatile oil of wintergreen and sweet birch may be distilled as a colorless oil with the characteristic wintergreen odor so commonly known.

In addition to the two plants mentioned containing glucosidal substances which split up into a volatile oil and a sugar, the ordinary bitter almonds and peach, apricot, and prune kernels may be mentioned. These kernels contain the glucosid amygdalin, which when hydrolyzed yields benzaldehyde, hydrocyanic acid, and glucose, as follows:

$$\frac{C_{20}H_{27}NO_{11}}{\text{amygdalin}}+2H_2O=\frac{HCN}{\begin{array}{c}\text{hydro-}\\\text{cyanic}\\\text{acid}\end{array}}+\frac{C_6H_5CHO}{\begin{array}{c}\text{benzalde-}\\\text{hyde}\end{array}}+\frac{C_6H_{12}O_6}{\text{glucose}}.$$

Therefore, when the ground kernels are macerated or hydrolyzed in the presence of water and then distilled, the ordinary volatile oil characteristic of bitter almonds and of peach, prune, and apricot kernels, is obtained.

These kernel oils are in every way identical, just as the oils of wintergreen and sweet birch are practically identical, the former consisting chiefly of hydrocyanic acid and benzaldehyde and the two latter of nearly pure methyl salicylate.

One other example of an oil produced by fermentation is the oil of mustard seeds. These seeds contain the glucosid sinigrin, which likewise suffers hydrolysis when ground seeds are macerated in water, producing the volatile oil of mustard (allyl iso-sulphocyanid), glucose, and potassium acid sulphate, according to the following reaction:

$$\frac{C_{10}H_{16}NS_2KO_9}{\text{sinigrin}}+H_2O=\frac{C_3H_5CSN}{\begin{array}{c}\text{allyl iso-}\\\text{sulpho-}\\\text{cyanid}\end{array}}+\frac{C_6H_{12}O_6}{\text{glucose}}+\frac{KHSO_4}{\begin{array}{c}\text{potas-}\\\text{sium}\\\text{acid}\\\text{sulphate}\end{array}}.$$

The fermented mixture readily yields the volatile oil by distillation with steam. The medicinal action attributed to mustard seeds is due to the mustard oil developed in the reaction mentioned. This oil, however, is not formed until the mustard is brought in contact with water, thus enabling the vegetable ferment to hydrolyse the glucosid, with the results specified.

These instances are cited here simply to make clear the fact that not all volatile oils preexist in plants and that some of our most valuable oils are obtained from plants entirely devoid of odor, which, however, develops when the proper conditions are supplied. The number of these special cases is comparatively few when we consider the vast number of plants which contain volatile oils existing as such in their tissues and depending for their development in the plant only on conditions of growth and nourishment.

EXTRACTION OF AROMA.

For the separation of the aromatic principle from a plant, several methods are in vogue, depending for their efficiency and practicability largely upon the nature of the odors to be extracted. The properties of the various odorous substances are such that in order to separate them in their entirety only such methods can be applied as will bring about the least possible change in the fragrant constituents. Because of the facility with which certain aromatic principles undergo change it is necessary at times to extract the perfume without exposing the materials to high temperatures and to other conditions which would tend to change their chemical nature. For this reason several methods are employed at the present time for the extraction of volatile oils and perfumes, each of which possesses advantages and disadvantages.

The following general methods find application in commerce for the separation of the odoriferous principles from plants and plant products: (1) Solution, (2) expression, and (3) distillation.

SEPARATION OF PERFUMES BY SOLUTION.

The method of solution as applied in practice is subdivided into three modifications, viz, by volatile solvents, by liquid fats, and by solid fats.

EXTRACTION WITH VOLATILE SOLVENTS.

The method of extraction with volatile solvents, such as ether, chloroform, benzene, petroleum ether, acetone, etc., is adaptable only to flowers, because of the comparatively small quantity of other kinds of extractive matter soluble in any one of these solvents. The method would be very impractical for the extraction of perfumes or oils from a whole plant or from the leaves of a plant, since whole plants or plant parts other than flowers contain considerable other matter besides the essential oil soluble in these solvents.

The method employed commercially for the extraction of odors by means of these volatile solvents embodies a process known as continuous extraction. By this method the solvent, after percolating through flowers and carrying with it in solution the odorous constituents, is heated in a proper receiving vessel and the vapors condensed and utilized further for extracting any remaining odor. The advantage of this method is the small amount of solvent necessary for extraction and the continual percolation of fresh solvent through the material.

The accompanying illustration (fig. 1) represents an apparatus used for this purpose, which consists chiefly of the percolator, the receiving vessel, and the condenser.

The percolator, *B*, in the bottom of which is placed a circular screen, is charged with the flowers to be extracted, and the removable cover, *F*, is attached by means of clamps, as indicated. A heavy gasket of cotton wicking or asbestos (previously moistened) or rubber is placed between the cover and the percolator to insure a tight connection. To the bottom of the percolator at *H* is attached the receiving vessel, *A*, and the hot water steam bath, *D*, by means of a screw union. Into the cover, *F*, is fitted a perforated rubber cork, through which passes a glass tube, *K*. The glass tube, *K*, is further connected with the condenser, *C*, by means of a perforated rubber stopper. The condenser may be of the single-tube or worm variety, the former being preferable. The tube *K* is of glass for the purpose of enabling the operator to observe the rapidity with which the condensation of vapors is taking place. After pouring the solvent through the condenser and into the percolator, heat (preferably steam or hot water) is applied to the bath, *D*. The steam is passed through the bath, *D*, in the direction indicated by the arrows. The solvent which has percolated through the flowers in *B* is

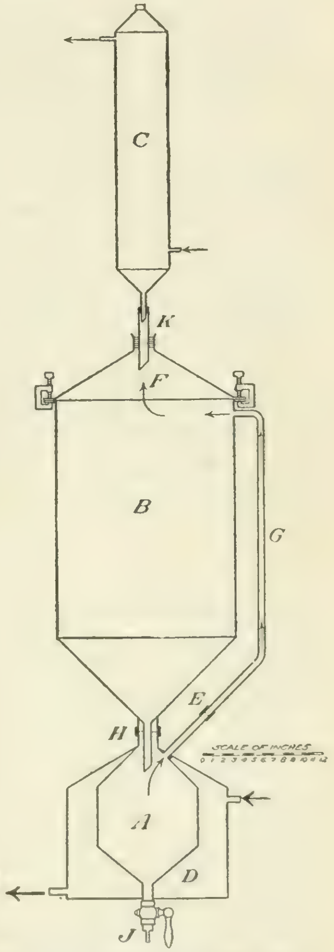

FIG. 1.—Continuous extraction apparatus. *A*, Receiving vessel; *B*, percolator; *C*, condenser; *D*, bath; *E*, union; *F*, cover; *G*, tube; *H*, union; *J*, drain cock; *K*, glass tube.

vaporized and driven up through the tube *G* (which should be covered with asbestos to prevent radiation) and into the percolator, thence into the condenser, where the vapors are condensed and drop back into the material. A continuous extraction is thus obtained with a minimum quantity of solvent.

For the final recovery of the solvent from *A*, the apparatus, after cooling, is disconnected at *H* and a screw cap attached to the neck of *A*. The tube *G* is disconnected at the union *E*, which may be connected with the condenser in proper position, and heat applied to *D*. The excess of the solvent is completely recovered in this manner, the resultant oil or perfume being drained off by opening the cock, *J*.

The chief disadvantage of an apparatus of this type is its narrow field of usefulness, which is practically restricted to the separation of perfume from flowers. When this apparatus is used for the extraction of other parts of the plant which may contain aromatic substances, the oil is liable to be contaminated by resins, waxes, etc., which would be extracted with the perfume by the solvent used. In order to purify further the crude oil obtained, steam distillation must be resorted to, in which case the delicate quality of the perfume obtained by the cold extraction would probably suffer slight changes induced by the steam.

EXTRACTION WITH LIQUID FATS.

The process of extraction with liquid fats is comparatively simple and depends upon the ability of a liquid, fatty oil to absorb the odors from flowers. For this purpose olive oil, lard, or other bland fixed oils may be advantageously used. The oil is placed in a kettle or vat (preferably porcelain lined) and heated to a temperature of 40° to 60° C.; the flowers to be extracted are then introduced either directly into the fatty oil or inclosed in coarse bags and suspended in the fat. The material is maintained at this temperature for a time varying from one-fourth to one and one-half days, when the mixture is either drained to remove the flowers or the bags are removed and expressed and recharged with fresh material. In this manner a perfumed oil is produced from which the perfume may be extracted by shaking out with strong alcohol, in which the odor is soluble and the fat insoluble. The fatty oil, which still retains traces of the flowery fragrance, may be used for further extraction of the same flowers.

This method of maceration in liquid, fatty oil is carried on to some extent in the perfume gardens of southern France and Germany, where perfumed oils are largely manufactured from such flowers as rose, jasmine, violet, tuberose, cassie, etc.

The extraction by maceration is advantageous because of its ease of operation and manipulation, but owing to the fact that heat is necessary for the rapid absorption of the perfume, another method in which the fat is used as a cold absorbing medium has been devised and used.

EXTRACTION WITH SOLID FATS.

The process of absorption of perfumes in cold by means of fats, the "enfleurage" process, has long been used for the extraction of the more delicate odors, and is possibly more universally used than any other process for the preparation of certain flower odors.

The great avidity with which some solid fats absorb aromatic substances is the basis of the method. Odors of nearly every description are absorbed by neutral solid fats when the latter are placed adjacent to or in contact with the odoriferous substances.

The enfleurage process, which is based upon this peculiar property of fats, was originally carried out by spreading freshly picked flowers upon a thin layer of lard spread upon glass plates, the flowers being allowed to remain in contact with the lard until exhausted, when the apparatus was charged with fresh flowers. In this manner a perfumed pomade was produced containing the natural odor of the flowers.

For effecting a separation of the perfume from the solid fat, which is desirable in some cases, advantage is taken of the comparative insolubility of the fat in strong alcohol and the ready solubility of the perfume. Therefore, in preparing the pure perfume, the perfumed pomade is thoroughly and repeatedly agitated with alcohol, an alcoholic extract or perfumed essence resulting. This resulting extract is sometimes employed as such for producing delicate scents. In order to obtain the pure oil from the alcoholic extract, the alcohol is evaporated carefully in a vacuum, the concentrated oil or perfume of the flowers remaining. These concentrated oils, although often rather unpleasant in odor in extreme concentrations, produce an exquisite aroma when diluted.

The crude process of enfleurage just mentioned has been largely modified in recent years in order to promote rapidity of operation, to protect against loss of odor by nonabsorption, and to obviate the actual contact of the flowers with the lard. When the flowers are in actual contact with the lard there is a tendency toward the absorption of undesirable substances.

A practical apparatus of this nature (fig. 2) consists of a box, *H*, about 2 feet square and 6 feet high, so constructed as to be practically air-tight. In the lower portion of the box, which is supported about 2 feet above the floor, is placed a layer of sponges, *G*, or other porous material capable of holding moisture. The bottom of the sponge tray may be constructed of light copper gauze or brass gauze to permit the free access of air. Directly above are located the flower trays, *A*, *B*, *C*, *D*, and *E*, which also have brass or tinned-iron screens of rather coarse mesh for bottoms. The sides, fronts, and backs of trays may be of wood. The trays may readily be placed in or taken out of the absorption box when refilling is necessary. Immediately above the flower trays are located a series of glass plates so constructed that they may be readily taken from the box and replaced. The absorbing medium, lard or other solid fat, is spread in a layer about one-half inch in thickness upon each glass plate, which is placed in its proper position. The front portion of the apparatus must be supplied with a tight-fitting door (not shown in the illustration) capable of being opened or removed to admit of charging and discharging the fat and flowers. When the flower trays have been charged with the freshly picked flowers and the door closed firmly a current of air is made to pass upward through the sponges and the flowers and the lard-laden tray, a more efficient circulation being produced by the alternating arrangement of glass plates. The odor-bearing air as it passes over the lard readily surrenders its perfume, which can be subsequently extracted from the lard. A small fan may be placed at the top of the apparatus or a blower at the bottom to produce the required movement of the perfume-laden air. The current should be regulated so that absorption is completely effected in its upward journey.

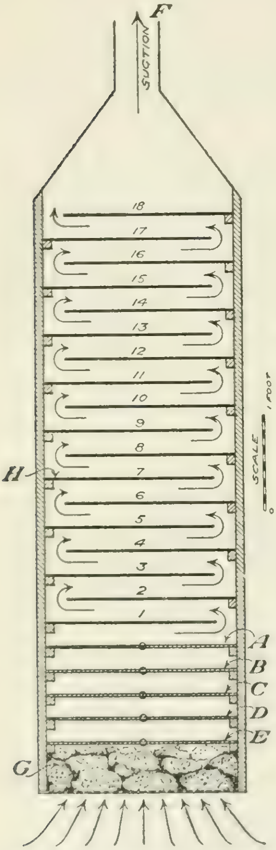

FIG. 2.—Apparatus for treating flowers by the enfleurage process. *A*, *B*, *C*, *D*, *E*, Flower trays; *F*, exit; *G*, sponge tray; *H* (1–18), glass plates.

When retained in fresh condition, flowers hold their aroma and even secrete perfume for a longer period of time than if allowed to wilt and dry; hence the moistened sponges in the bottom of the apparatus. Some flowers are even known to continue to secrete perfume if left in moistened air. The air drawn through the apparatus is moisture laden and therefore produces the best yield of perfume from the flowers.

The operation of the above contrivance may be continued with only such interruption as is required for recharging with fresh flowers when practically all odor has been drawn off. After the lard has been thoroughly charged, the perfume held in solution is separated by a thorough agitation of the pomade with strong alcohol, preferably by means of a shaking or churning device in which the pomade is continually agitated and beaten in order to expose the largest surface possible to the solvent action of the alcohol. There results from this extraction operation an alcoholic extract of the flowers which possesses the natural odor to a very high degree. Because of the fact that no heat is necessary, the resulting extract is far superior to an extract prepared by the process of heating with liquid fats.

It is to be remembered, however, that the yield of perfume from some of the more delicate flowers, such as violet, cassie, tuberose, jasmine, etc., is rather small, which accounts largely for the exceedingly high prices of the extracts or pomades of these flowers.

Usually it is impossible to extract the odor from the pomade completely, even when extracted successively with fresh portions of alcohol. The fat after extraction still retains the characteristic aroma and may be used in this form or may be again spread upon the glass and utilized for further absorption from the same kind of flowers.

The amount of labor required for this work is necessarily large when the fact is taken into consideration that the flowers require hand picking. The time consumed by the entire process from the picking of the flowers to the finished extract is also very considerable. However, the quality and, consequently, the prices of these exquisite odors usually offset unfavorable conditions of labor and time in regions where this industry is carried on commercially.

SEPARATION OF PERFUMES BY EXPRESSION.

Another class of volatile-plant products already cited is so localized in the plant as to admit of the extraction of the oil by a different yet extremely simple process. The class of products referred to includes the citrus fruits, namely, the lemon, orange, bergamot, and other related fruits. Owing to the fact that the oil contained in these fruits is deposited in the outer portion of the peel and is therefore very accessible, the method of expression is peculiarly adapted to the citrus fruits and products.

There are several methods applicable to the extraction of the oil from the peel of the lemon, orange, and bergamot, all of which, however, embody the same principle, namely, the rupturing or breaking of the glands containing the oil and the collecting of the oil after it has been released.

In the method known as "écuelle à piquer," the rinds of the lemons are rubbed in hollow cups (écuelle, fig. 3) lined with sharp points, which lacerate the oil glands and allow the oil to exude.

This method has been largely displaced by the simple expression of the oil.

Owing to the ease with which the peels of the fruits liberate the oil, a method of expression is applied very conveniently to the separation of the oil. Usually the peels from half sections of the fruit are turned inside out and pressure brought to bear on the outer surface in such a manner as to rupture a large majority of the oil vessels. The oil thus liberated is collected upon a sponge, which absorbs it and from which it is subsequently squeezed. By this method, known as the "sponge method," the larger part of the oils of the lemon, the orange, and the bergamot is extracted, the operation being carried on usually at night, when other activities in the fruit work are at a standstill.

Expression by the sponge method is far from complete because of inability to bring pressure upon every portion of the peel; hence, after the "hand-pressed" oils, which are generally conceded to be the best grade, are obtained the peels are placed in a power press or in a crude still and the remaining oil is separated. This latter forms a secondary oil of commerce, generally considered to be much inferior to the sponged oil.

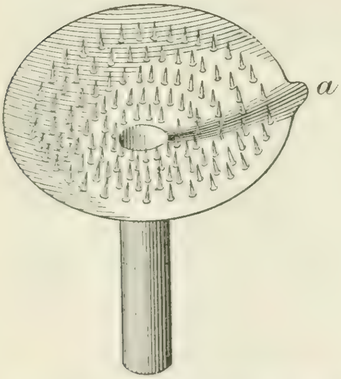

FIG. 3.—Écuelle for lacerating the oil vessels in the peels of oranges, lemons, etc. *a*, Draining lip.

The use of a mechanical device for rupturing lemons and bergamots and for expressing the oil from them has been introduced into some producing districts of Europe. However, only a small percentage of the oils is extracted in this way, the sponge system being most usually adopted.

Whether the process of steam distillation, which will be discussed later, if somewhat modified would produce a grade of oil equal to the hand-pressed oil is doubtful. At any rate, the oil containing only traces of compounds capable of decomposition at the usual temperature of steam, it should not be greatly inferior, production by this method would be easier, and its cost would be materially less.

SEPARATION OF PERFUMES BY STEAM DISTILLATION.

A simple still, which consists essentially of three parts, the still body, the condenser, and the receiver, with a suitable means of applying direct heat to the still body, containing material suspended in water, was used early in the eighteenth century. Even at the present time many smaller distillations are still carried on with this form of apparatus. The chief disadvantage of this type of still lies in the fact that the heat, being applied directly, has a tendency to char or burn the materials adjacent to the bottom, and thus appreciably affect the quality of the aromatic product distilled over.

This method has been largely superseded in modern times by distillation with steam, the principles of which depend upon the property of the steam as it passes through the charged apparatus to carry with it the volatile portion of the plant in the form of vapors, which are condensed, together with the excess of watery vapor, and deposited in the receiving vessel. The three steps in the process are (1) the distilling, (2) the condensing of the vapors, and (3) the collecting of the oil. Even though the boiling points of the volatile oils separated by distillation from plants may be considerably higher than the temperature of steam, the odors are readily liberated by the passing steam and carried over.

APPARATUS.

The apparatus required for the three processes which collectively constitute steam distillation is of comparatively simple construction, consisting of (1) a still, (2) a still head (cover for body), (3) a condenser, and (4) a receiver.

The body of the still, or the receptacle in which is placed the material from which the oil is to be extracted, gives best results when cylindrical in form and may be constructed of various materials, preferably copper. However, some stills are made with wooden bodies. Galvanized iron heavily tinned on the interior is a suitable material, principally because of its cheapness and durability. The still may be constructed of any size desirable, provided the other parts, the condenser and the receiver, are in proportion, depending upon the amount of material to be used and the extent of production desired.

In figure 4, *A* represents the still, *B* the still head, or cover, *C* the condenser, and *D* the receiver. Through the side of the still at the point *E* passes a galvanized steam pipe from three-fourths to 1 inch in diameter, extending downward and finally terminating in the middle of the still, as shown by the dotted line. A spigot, *F*, is attached to the bottom of the still for draining the collected water from the apparatus. About 3 inches from the bottom of the still is placed a coarse screen, *H*, fastened to a wooden frame, which acts as a support for the herb or plant part to be distilled. Encircling the top of the still is an iron collar, which may be conveniently constructed of angle iron, to which the copper or the metal is securely attached.

The still head, or cover, *B*, is of the same material as the still and is slightly conical in shape, with an exit tube terminating in a union, at which point connection may be made with the condenser. Around the periphery of the cover is securely fastened a flat collar of iron of the same diameter as the angle iron used on the top of the still, so that with the cover in place the two will exactly coincide.

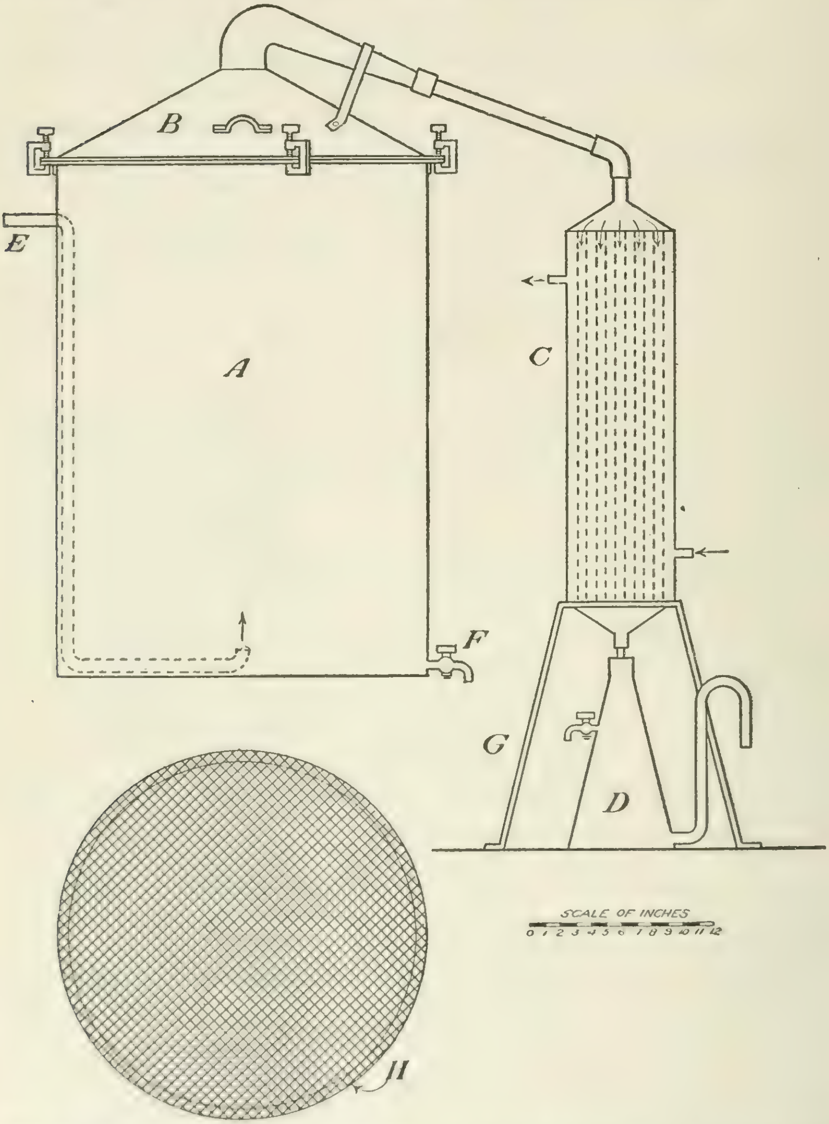

FIG. 4.—Distilling and condensing apparatus. *A*, Still; *B*, still head or cover; *C*, condenser; *D*, receiver; *E*, steam pipe; *F*, spigot; *G*, tripod; *H*, screen.

The condenser, *C*, as shown in figure 4, consists of a group of tubes (inside diameter one-half to 1 inch, depending upon the size of the condenser) surrounded by an outside jacket fitted with an inlet tube at the bottom and an outlet tube at the top, to enable cold water to pass continually through the condenser in an upward direction. The condenser is attached to the still by means of the union joint, as illustrated.

The tripod, *G*, acts as a support for the condenser while the apparatus is in operation and also while the still is being charged or discharged. Under the bottom opening of the condenser is placed a receiver, *D*, of copper, with a goose-neck siphon tube extending from the bottom to within 2 inches of the top. On the side opposite the siphon tube is fastened a small brass spigot to admit the removal of the oil from time to time.

For the generation of steam, if a source is not otherwise available, a small boiler, such as is illustrated in figure 5, may be conveniently used. A small boiler, *A*, of light boiler iron fitted with about a dozen flues is capped by the cover, *B*. Other usual accessories are attached, viz, water gauge, *C;* pop valve, *D;* water gauge, *E;* and steam outlet, *F*. The boiler may be preferably set upon a gasoline stove or an open-fire stove or on a tripod with an open fire beneath. The pop valve may be set at about 8 to 10 pounds, no greater pressure being necessary. To replenish the water in the boiler a funnel tube attached to the pop valve may be used. Connection to the still is made most conveniently by the attachment of a short piece of rubber steam hose to *F*, as this admits a ready detachment from the still when distillation is completed. A pressure of 5 to 10 pounds of steam is sufficient for ordinary distillation. The size of the boiler may be slightly increased if distillation is to be conducted on a larger scale.

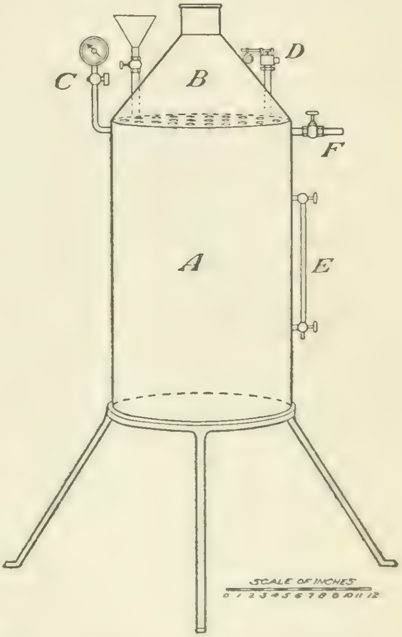

FIG. 5.—Steam generator. *A*, Boiler; *B*, cover; *C*, steam gauge; *D*, pop valve; *E*, water gauge; F, steam outlet.

The boiler just described possesses efficiency enough to distill charges of 75 to 150 pounds of herb.

For distillation on a commercial scale a large, stationary, upright boiler may be installed for the generation of steam, or, if convenient, steam may be taken from any high-pressure boiler which may be in use for other purposes. The volume necessary being very slight, indeed, is scarcely perceptible upon the steam gauge.

METHOD OF OPERATION.

To charge the still, place the false bottom in the still and pack the herb firmly until completely filled. Place a gasket of asbestos rope, heavy cotton wicking, or other suitable material (previously moistened) around the top of the still. Place the cover upon the moistened gasket and clamp securely with heavy steel clamps. Connect the exit pipe from the top of the still to the condenser by means of the union, as indicated in the diagram. Now conduct steam into the still through the inlet pipe, *E*, slowly at first, and regulate afterwards so that the distillate passing from the end of the condenser is cold or but very slightly warm. The receiving vessel, *D*, should be previously filled three-fourths full of water and placed under the exit from the condenser. Likewise, the cold water is started flowing through the condenser, as indicated by the arrow. Frequently the oil may be led from the receiver by opening the cock on the side. However, owing to the siphon tube attached to the receiver, overflowing is impossible, since this tube carries off the water which separates in the bottom of the receiver. To ascertain when distillation is completed a few drops of the distillate as it comes from the condenser are collected in a glass test tube. The appearance of oily globules on the surface readily indicates whether appreciable quantities of oil are still passing over. Usually a distillation is completed in from one and one-half to two and one-half hours.

The advantage of steam distillation over other methods of volatile-oil extraction lies principally in its wide applicability and speed of operation. Most plants or plant parts, with the exception of the flowers in some few cases, may be extracted most readily and most expeditiously and with a minimum amount of labor by the steam-distillation method. The simplicity of the operation is obvious. The removal of the oil is much more complete than by any other process. Furthermore, there is produced as a by-product during the distillation an aqueous distillate which is completely saturated with the oil. The aqueous distillate may in many instances be utilized and sold as an "aromatic water" of commerce, especially in such cases as lavender, orange flowers, rose, etc. The aromatic waters possess excellent odors, largely because of the extreme dilution of the odorous compounds held in solution, and are useful in the perfumery and toilet-preparation industries. When the aqueous distillate from the plant has no marketable value, it may be profitably collected and returned to the boiler. In case of a further distillation of the same plant it will materially add to the yield of oil, since the distillate is a saturated solution of the oil. Many oils are extremely soluble in water. Distillates from oils of this class usually augment considerably the yield of oil when returned to the boiler and transformed into steam and oil vapors.

The spent herb, which on a large scale amounts to no inconsiderable quantity, may be used as fuel and the ash used as fertilizer, or it may be scattered upon a field and plowed under as a mulch. In some cases the spent herb serves as a useful stock food, an example of which is the peppermint grown in Michigan.

The advantages far outnumber the disadvantages of the distillation method, the only disadvantage being the possibility of slight decomposition of the ester bodies in some of the more delicate perfumed plants. However, this is only slight and almost negligible in most herbs.

HANDLING OF VOLATILE OILS.

PURIFICATION.

The volatile oil as it comes from the still is in a crude state, being contaminated by volatile substances which are formed during the distilling process by the action of the steam upon the less stable plant constituents, decomposing them into volatile organic substances, which, although trifling in quantity, nevertheless tend to affect the color, odor, and taste of the oil.

The chemical changes taking place in the still are numerous, the more important being oxidation and reduction of some of the constituents of the oil, as well as of the other plant constituents, saponification of the more unstable esters, and resinification brought about by a polymerization of certain plant constituents, all of which aid in forming volatile substances which mingle with the oil.

Although a process of purification is not always applied to these crude oils, it is important and sometimes highly profitable to subject the crude product to a process of rectification. By rectification is meant a redistillation of the oil with steam, this procedure affecting a moderate separation of the undesirable substances which may have been formed. The substances which detract from the odor of the oil are usually left behind in the apparatus as a heavy, malodorous liquid slightly resinous in character. Rectification usually results in a fine, finished product, free from foreign odors, and leaves an oil much more presentable in color as well as in odor and taste.

This process may be conducted in a miniature still built on the same general plan as the large commercial still. The loss in the amount of oil is more than compensated for by the better quality and the increased salability of the rectified oil.

SEPARATION, FILTRATION, AND DRYING.

To separate the oil from the aqueous distillate in the receiving vessel, the portion which has not been separated by means of the stop cock on the side of the receiver is poured into a separating funnel of glass and the heavier liquid drawn off. The oils resulting from different distillations of the same plant are then united and subjected to filtration, which process tends to separate any solid particles or emulsion of oil and water. Filtration is conveniently effected by pouring the oil into a glass funnel which has been fitted with a filtering medium, such as filter paper (an unsized, porous paper) or cotton. When cotton is used as a filtering medium a small tuft may be fitted loosely into the neck of the funnel and oil poured upon it. Usually filtration takes place more rapidly through cotton than through paper and with much less loss. Rapidity of filtration is essential to minimize the possibilities of changes taking place in the oil by oxidation, since the oil is more or less exposed to the action of the air and light while undergoing this clarifying process. Hence cotton is to be recommended.

Just as the water that comprises the aqueous distillate is a saturated solution of the oil, so the oil which floats above the distillate is saturated with water. Usually it is of prime necessity that the moisture be removed from all oils, first, because of the subsequent changes that are likely to occur if moisture is present, and, second, because of the turbidity which water imparts to the oil. Hence, after filtration through cotton the oil should be dried by shaking in a bottle with a dehydrating substance, such as anhydrous calcium chlorid or anhydrous sodium sulphate, preferably the latter, owing to its lack of action upon the constituents of the oils. The crude sodium sulphate (Glauber's salts) may be dehydrated by heating it in a vessel over direct heat, with constant stirring until a dry, grayish powder results. But a small quantity is necessary to abstract the moisture from an oil. After the oil has been dried it is again filtered through a light plug of cotton. A clear and transparent oil finally results, bearing in every way the appearance of a marketable oil.

PRESERVATION.

Many constituents of volatile oils are of such a nature that unless the strictest precautions are observed in storing the oils chemical decomposition takes place, causing them to change in both odor and color, thereby reducing the quality and value. The esters of an oil (combinations of organic acids with alcohols) are very prone to decomposition, as are also many aldehydes and hydrocarbons, which either through saponification, hydration, oxidation, reduction, or polymerization become totally different substances. These chemical processes are usually stimulated by the action of light and air upon the oils. Therefore, in order to guard against these changes and to minimize them as much as possible, the strictest attention should be paid to the proper bottling and storage of the oils.

It is of the utmost importance that all oils should be placed in bottles which are well filled. The absence of air is of the greatest importance in insuring the preservation of an oil. The oxygen of the air, assisted by light, becomes extremely energetic in bringing about some of the changes previously mentioned. It is therefore of import that the oils be kept not only in well-filled, tightly stoppered bottles, but in a dark place. It is sometimes convenient and advisable to use amber-colored bottles in order to prevent the entrance of the actinic rays of light which are so active in causing polymerization. A cool place is also to be preferred for the storage of volatile oils.

All undue exposure of oils to the action of light and air should be avoided as much as possible. It is necessary that an oil from the time it leaves the receiving vessel after distillation or rectification until it is filtered, dried, and bottled should be handled with care and dispatch to insure a product of the best quality and appearance.

GROWTH AND HARVESTING OF PERFUME PLANTS.

CLIMATE AND SOIL.

Up to the present time the cultivation of perfume-yielding plants has not been carried on, even experimentally, over a very large part of the United States, and such work of this sort as has been done is confined to but a few kinds of plants. Until our knowledge along these lines has been very much increased by practical attempts to cultivate this class of products, only statements of probabilities can be made. However, in some cases plant introductions along other lines from the oil-yielding countries of the Old World, together with information as to conditions of climate and soil in those regions, give a basis for surmise in connection with these crops. The wide diversity in climate and soil in different parts of the United States, with the varying conditions of heat, light, and moisture, renders it probable that some portions of the country will be found to be well fitted for the cultivation of the perfumery plants characteristic of the temperate zones. It appears probable that the conditions prevailing in those parts of Europe associated with the perfumery industry can be fairly well duplicated. It will doubtless require much experimental work to find the particular localities best suited to special plants.

It must be borne in mind, however, that not only must conditions of soil and climate be right but that the labor conditions which go with the problem must be met in a practical way. The distance of the point of production and the transportation factors are also important and might be decisive.

Some work on perfumery-plant growing has been carried on in Florida, notably by Mr. E. Moulié, of Jacksonville, whose experience has been distinctly encouraging. Experiments by Mr. S. C. Hood with a number of oil-yielding grasses grown in the testing garden carried on by the Bureau of Plant Industry at Orange City, Fla., give good ground for hope that a number of kinds of plants able to endure a little freezing weather may be cultivated with good results. California and the arid Southwest offer promising conditions for plants which thrive in dry, sunny locations. Michigan, Indiana, and New York are already well known as important centers for the production of peppermint, spearmint, and erigeron oils, while Michigan, Wisconsin, Nebraska, and other States in the north-central part of the country form a most important source of wormwood oil. Doubtless other oil-bearing plants now on trial may be found to do well in parts of the same general section. American wormseed (*Chenopodium* spp.) is distilled in Maryland and southward, and sassafras is distilled in various places, especially in the mountains, from Pennsylvania southward. The oils of wintergreen, sweet birch, spruce, and white cedar are derived from the more northern ranges of the Atlantic slope. The mountainous regions of Tennessee and Kentucky supply wintergreen, sweet birch, and sassafras oils.

It is thus apparent that a number of native and introduced plants rich in volatile oils have obtained foothold on a commercial basis in this country, and there is good ground to hope that products of this general class now obtained from abroad may in time become naturalized here.

GROWTH AND CULTIVATION.

Several methods of procedure with regard to the propagation and cultivation of volatile-oil and perfume-yielding plants are to be followed, depending largely upon the nature and habitat of particular species of plants. Annual plants such as are grown from seeds and which blossom and mature the same year are rather common among volatile-oil plants.

The details of cultivation and handling vary somewhat with the crop grown and are a matter for careful field study. In general, the annuals are either fall or spring sown, depending upon soil and climate, some seeds germinating best if left in the ground over winter, as is the case with pennyroyal. Row culture is advisable in order to secure better cultivation and a consequent freedom from weeds.

Perennials are in some cases grown well from seed, as caraway and wormwood, but in some cases, such as spearmint, peppermint, sage, rose, and lavender, propagation from cuttings or roots is preferable.

The method of handling must be adapted to the particular plant to be grown.

A thorough cultivation of the field is necessary to eliminate all weeds, both between the rows and in the rows themselves. This is of the utmost importance, since weeds, although as a rule not containing any volatile oil, do possess volatile substances which are set free by the steam should the weeds become mixed with the aromatic plant. A contamination of the oil and a depreciation in the aromatic qualities will result unless the material is kept free from weeds and other rank growths.

HARVEST.

Possibly no stage in the cultivation and production of volatile oils from plants is of greater importance than that of the proper harvesting of the crop. It is usually conceded that most perfume plants reach their maximum development as regards odor, both in quality and quantity, at the flowering period. On the other hand, many authorities are of the opinion that as soon as a plant reaches its full flowering period there sets in a gradual consumption of the odorous principles; hence, the harvest should be made prior to this consuming process.

Experiments recently conducted for the purpose of determining the amounts of odorous constituents of several plants present at various stages of development seem to indicate that both the quality and the quantity of the oils vary appreciably during their successive stages of development, but no evidence was obtained to show that consumption of odor took place during flowering. However, it was proved that the odor was developed during the advance in growth and the approach of the flowering period.

Three typical plants were used as a basis of experiment, viz, peppermint (*Mentha piperita*), bergamot mint (*Mentha citrata*), and wormwood (*Artemisia absinthium*), the oil of each of which owes its characteristic fragrance to esters which admit of being measured quantitatively with some accuracy. The plants were grown under like conditions and distillations conducted at three well-defined stages of advancement, namely, (1) before flowering (or while in the budding state), (2) at flowering, and (3) after flowering (or during the fruiting stage).

The effect of successive stages of growth upon the esters and the alcohol only will be considered here, although other constituents, and especially the terpenic compounds, also suffer changes.

To picture more clearly the results of the experiments and the changes observed in the oils, tabulations were made as follows:

TABLE I.—*Yield of oil and changes observed in plants at different stages of growth.*

PEPPERMINT (MENTHA PIPERITA).

Stage of growth.	Yield of oil.	Ester content as menthyl acetate.	Alcohol content as free menthol.
	Per cent.	*Per cent.*	*Per cent.*
Before flowering (July 22)	0.23	9.5	31.0
At flowering time (August 21)	.20	14.5	23.6
After flowering (September 25)	.10	24.0	34.0

BERGAMOT MINT (MENTHA CITRATA).

Stage of growth.	Yield of oil.	Ester content as linalyl acetate.	Alcohol content as linalool, free.
	Per cent.	*Per cent.*	*Per cent.*
Before flowering (July 20)	0.32	47.6	7.3
At flowering time (September 22)	.37	55.0	7.3
After flowering (October 14)	.22	52.0	5.5

WORMWOOD (ARTEMISIA ABSINTHIUM).

Stage of growth.	Yield of oil.	Ester content as thujyl acetate.	Alcohol content as thujyl alcohol, free.
	Per cent.	*Per cent.*	*Per cent.*
Before flowering (July 2)	0.19	26.0	14.7
At flowering time (July 14)	.18	32.5	11.7
After flowering (August 4)	.10	47.5	12.0

It is obvious from these results that in two cases, with peppermint and with wormwood, the aromatic quality of the oil, if measured by the percentage of esters, is increased gradually during each stage of growth, the percentage of free alcohol remaining fairly constant. In the peppermint the oil from the "after-flowering" stage was noticeably more fragrant than the oils from the two earlier stages. The yield of oil remains fairly constant up to the last stage, when there is a marked diminution. The plant in the first two stages is very much the same as regards moisture content, while the low percentage of oil from the plant after flowering, when it possesses much less succulency, may be attributed to the consumption of other constituents than the esters and alcohol. This applies to all of the plants which seem to follow the same general course in this respect.

The oils from the bergamot mint disclose a very slight decrease in ester content and alcohol content in the "after-flowering" stage.

The decrease is so slight, however, as not to warrant the statement that a consumption of odor has occurred.

It must be understood that these results are proposed only tentatively and that further experiments will be carried on to prove or disprove the conclusions drawn.

Employing the aforementioned plants as typical examples, the harvest period, in order to attain a maximum yield of oil with a correspondingly high percentage of odorous constituents, should begin as soon as the plant is fully blossomed. A delay of the harvesting until the "after-flowering" stage is reached apparently increases somewhat the quality of the odor, but this increase is largely overbalanced by the decrease in the yield of oil, which is of paramount importance to the grower.

The proper preparation of the material prior to distillation is not to be overlooked, since the quality and the quantity of the oil are varied considerably by improper handling and by partial or complete drying of the fresh plant before it enters the still.

To illustrate this point more clearly, practical instances will be mentioned to show the effect of drying upon the quality and the quantity of the oil from plants. The three examples previously mentioned will be used as a basis for the comparison of the oils from fresh and dry material. In order to obtain a rational and logical means for comparing the oils, fresh, green plants of peppermint, bergamot mint, and wormwood were cut during the height of their blossoming stage. The herb in each case was divided into two equal parts, one half of which was set away to dry and the other half distilled immediately. The oils obtained were later analyzed for the esters and the alcohols, and the results obtained are presented in Table II.

TABLE II.—*Yield of oil and percentages of esters and of alcohols obtained from fresh and from dry plants.*

PEPPERMINT (MENTHA PIPERITA).

Condition of plant.	Date of distillation.	Yield of oil.	Menthyl acetate.	Menthol.
		Per cent.	*Per cent.*	*Per cent.*
Fresh	August	[a] 1.50	10.5	48
Dry	December	.55	18.0	47

BERGAMOT MINT (MENTHA CITRATA).

Condition of plant.	Date of distillation.	Yield of oil.	Linalyl acetate.	Linalool.
		Per cent.	*Per cent.*	*Per cent.*
Fresh	September	[a] 1.30	33.0	45
Dry	December	.75	51.8	43

[a] Calculated from dry weight.

TABLE II.—*Yield of oil and percentages of esters and of alcohols obtained from fresh and from dry plants*—Continued.

WORMWOOD (ARTEMISIA ABSINTHIUM).

Condition of plant.	Date of distillation.	Yield of oil.	Thujyl acetate.	Thujyl alcohol.
		Per cent.	*Per cent.*	*Per cent.*
Fresh	August	0.60	32	41
Dry	December	.44	35	18

These data with respect to the oils from fresh and dry herbs readily illustrate that during the drying of the plants certain factors, assisted by exposure to air and light, undoubtedly bring about chemical changes in the aromatic constituents, which evidence themselves in the final analyses of the oils.

It will be noted that the yield of oil decreases 63⅓ per cent in the case of peppermint, while the percentage of decrease of oil from bergamot mint is nearly 43, and from wormwood about 27 per cent. These marked decreases are in part due to the long period of drying, but they at least show that there is a downward tendency, which is very natural considering the volatility of the constituents.

In all three cases there seems to be an increase in the percentage of esters, with a decrease in the percentage of alcohol, in the dried herb, the chemical changes no doubt being such as to facilitate the production of esters and to break down the alcohols. Apparently the alcohols seem to be more unstable, condensing with the organic acids in the plant under favorable conditions of heat, light, and moisture to form esters. This latter change is especially noticeable in all the oils, the dry-herb oils being considerably richer in esters than the fresh-herb oils, and correspondingly poorer in alcohols.

In order to produce the largest yield of oil from a given quantity of herb, distillation should be made immediately after harvesting. There is no noteworthy advantage in drying or even partially drying the plant, since the longer the time between the cutting and the distilling the more volatile oil will be lost by gradual evaporation or volatilization. Although the quantity of oil capable of being carried off into the air by simple drying seems only trifling, nevertheless, on a large scale the loss would be considerable. The increased proportion of the odoriferous esters in the oils from dry herbs is insufficient to warrant the drying of the plants before distillation, because of the loss of oil encountered during the drying process.

VOLATILE OIL PLANTS OF THE UNITED STATES.

At the present time the number of plants in the United States yielding volatile oils in a commercial way is very small, but the number capable of yielding oils of probable value is correspondingly great. There is, in fact, a large number of odoriferous plants still uninvestigated which should demand consideration. As yet but little research has been undertaken which would tend to increase the number of valuable aromatic plants now being utilized. A study of this particular phase of the subject, coupled with the introduction of foreign species into the United States, should eventually develop somewhat the resources of the country along this important line.

CULTIVATED PLANTS.

The relatively small number of volatile-oil-yielding plants at present under cultivation and the success of the industry based on these few plants should be sufficient justification for widening the scope of our efforts.

The cultivated plants at the present time are principally the mints, peppermint and spearmint, together with small quantities of such plants as wormwood, tansy, and wormseed.

The distillation of peppermint[a] and spearmint in the United States dates back to 1816, when the peppermint plant was first cultivated for the production of the oil in New York, followed somewhat later by spearmint. The cultivation gradually spread, until at present the center of the industry is in Michigan, with limited production in Indiana.

The cultivation in New York and Michigan has decreased recently, owing to a slight oversupply, which, however, is probably only temporary. Peppermint and spearmint are possibly more largely distilled in the United States than any other oils at the present time, excluding such plants as grow wild and which produce large quantities of oil, notably the turpentine-yielding pines.

The wormwood plant (*Artemisia absinthium*), although introduced from Europe, has been cultivated to some extent commercially in Wisconsin, Michigan, New York, and other North-Central States. The distillation of the oil has been conducted with a certain degree of success, the yield from fresh, flowering herbs being from one-third to one-half of 1 per cent. It is, however, questionable whether, in the light of the recent European agitation against wormwood, this plant will continue to be cultivated for its oil to the same extent as in the past.

The herb tansy (*Tanacetum vulgare*) is grown for its oil in a small way in the eastern part of the United States and yields from one-tenth to one-fifth of 1 per cent of a volatile oil used principally in medicine.

The plant American wormseed (*Chenopodium ambrosioides* L. var. *anthelminticum*) is grown chiefly in Maryland and southward.

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[a] Bulletin 90, pt. 3, Bureau of Plant Industry, U. S. Dept. of Agriculture.

where the plant is found growing wild. There are produced the seeds, which are valuable commercially, and the volatile oil distilled therefrom, which also possesses the anthelmintic action of the seeds.

Another volatile oil which is produced on a very extensive scale and which has been distilled commercially for more than a century, namely, oil of turpentine, deserves brief mention. The production of turpentine oil is confined principally to the Southern and Gulf States, from Virginia to Florida, regions of extensive pine forests. Turpentine is obtained as an oleoresinous exudation from several varieties of pine trees, chief among which is the long-leaved pine (*Pinus palustris* Miller). Other species, such as *Pinus taeda* L. and *Pinus echinata* Miller, also yield a valuable oleoresin. Unlike most volatile oils, the oil of turpentine is not distilled directly from the plant but results as one of the products of the distillation of the oleoresin obtained from the trees, the other product being the rosin or colophony of commerce. The usefulness and value of oil of turpentine in commerce, both in the arts and in medicine, where it is practically indispensable, require no further comment.

The plants just enumerated represent the principal volatile-oil plants which are cultivated or gathered for oil production in the United States. The distillation of oils from the mint species is a singular instance of an industry of commercial magnitude, while the several other oils which are being distilled from cultivated plants occupy a secondary position in production. The further development of some of the oils mentioned will be controlled largely by the consumption of the products and by the demand which may be created for them.

The experimental work being conducted at the present time at the Arlington Experimental Farm, near Washington, D. C., is such as to demonstrate the practicability of more extensive cultivation of the plants already grown, as well as of other plants growing wild at present, but which by proper methods of domestication can probably be greatly improved both from the standpoint of luxuriance of growth and of fragrance.

The introduction of foreign species of volatile-oil plants and the testing of the same upon native soil are also receiving considerable attention, and the successful production of oil is clearly assured in some cases. Suitable localities, however, must be chosen to conform with the natural habitats of the introduced plants in order to attain the highest degree of efficiency of production.

WILD PLANTS.

Possibly the number of wild aromatic plants which are used in the manufacture of volatile oils exceeds that of those which are at present cultivated. The extent of the production of the oils is much less, chiefly because of the more or less scattered condition of these plants, and therefore the difficulty of gathering them in large quantities. Usually these wild aromatic plants are distributed over wide areas confused largely with other volatile or nonvolatile species, thus causing the rapid collection of the plants to be seriously hindered. For this reason, probably, together with lack of interest in the cultivation of the wild plants, the production of their oils has been largely restricted.

SASSAFRAS.

A specific example of an important uncultivated plant which yields a volatile oil of considerable value is the sassafras tree. Sassafras oil was one of the first volatile oils distilled in America. The range of the tree is from Florida, where it was originally discovered, to Virginia and Pennsylvania, and even as far north as New York and the New England States. It is quite abundant in the South-Central States, especially Kentucky, Tennessee, and Arkansas. The production of this oil attained commercial significance early in the last century, and it is distilled extensively at present in Kentucky, Tennessee, Pennsylvania, Maryland, and Virginia; also to a less extent in Ohio, Indiana, and New York.

Although the distillation of this very fragrant oil, which is obtained principally from the bark of the root of the sassafras tree (*Sassafras officinalis*), has assumed a strong commercial aspect, the tree has not been grown, strictly speaking, for oil purposes. No doubt the great abundance and the ready accessibility of the trees growing wild are the causes of the noncultivation of this tree for commercial purposes. The leaves and branches of the tree are faintly aromatic, but are not used as a source of the oil. The root bark and wood, which contain from 1 to 8 per cent of volatile oil, form the crude source of supply. The oil is distilled by the ordinary method of steam distillation, the wood and bark of the root being previously coarsely comminuted to admit of better extraction.

WINTERGREEN AND SWEET BIRCH.

The distillation of the oils of wintergreen and sweet birch is a further example of wild aromatic plants furnishing oils in sufficient quantities to supply the trade. Both wintergreen (*Gaultheria procumbens*) and sweet birch (*Betula lenta*) occur largely from the New England States and North-Central States to Georgia, Florida, and Alabama. The distillation of these oils dates back nearly as far as that of the oil of sassafras and has developed until the industry at present is of some significance. Wintergreen and sweet birch are entirely unrelated plants, yet the oils produced from them by distillation are for all practical uses identical. Mention has been made previously of the fact that the oil in these plants is formed by reaction and does not preexist in the tissues. The glucosid gaultherin is the constituent which is responsible for the formation of this oil, and since the reaction between this glucosid and the plant ferment is the same in both plants, the resulting volatile oil (or methyl salicylate) must necessarily be similar.

In the case of the sweet birch, which is a tree of some size, the bark of the trunk and the small branches are used for distillation, being previously cut into small pieces and allowed to macerate with water before introduction into the still. A yield of three-tenths to three-fifths of 1 per cent of oil is obtained. On the other hand, for the separation of the oil of wintergreen the leaves and twigs are used, the plant being more or less shrubby. The same treatment is applied to wintergreen as to sweet birch, maceration in water being allowed to continue for a period of several hours prior to distillation. The yield of volatile oil from wintergreen varies from one-half to 1 per cent. Owing to the abundance of these plants their cultivation especially for the volatile oil has not been attempted, the material being collected from the plants as they grow in their native habitats. The strict enforcement of the Food and Drugs Act has tended to curtail largely the use of the synthetic oil (methyl salicylate) for certain purposes where the natural oil is required. A more active demand for the natural oils of sweet birch and wintergreen has necessarily resulted, the price of these oils being thereby materially advanced.

CANADA FLEABANE.

Several other plants capable of yielding volatile oils of some value are at present distilled in the United States. A very common herb growing abundantly in the North-Central and Western States, the Canada fleabane (*Erigeron canadensis*), usually regarded as a weed and known to westerners as the fireweed (not the true fireweed, however), is distilled in a small way in connection with the distillation of peppermint. The plant, which is a hardy annual, is not cultivated, but is cut in the wild condition, no special care being taken to eliminate other aromatic weeds or plants, and consequently there results an oil which, although representing the oil of erigeron, is far below the true standard of the oil, owing to the presence of extraneous plant matter introduced during distillation.

EUCALYPTUS.

The production of eucalyptus oil from the leaves and twigs of the blue-gum tree (*Eucalyptus globulus*) is of considerable importance in the volatile-oil industry of the United States. The commercial production of this oil is confined almost exclusively to the State of California, where the tree grows abundantly. The tree is not cultivated as a source of volatile oil, but is extensively grown for ornamental, fuel, and timber purposes. The leaves and twigs are collected from the waste branches or brush resulting when the trees are cut for timber or wood and used for the purpose of distillation. The material selected for distillation may be coarsely comminuted and the essential oil readily obtained therefrom by the usual method of steam distillation.

The yield of oil varies from three-tenths to four-fifths of 1 per cent, according to the quantity of woody branches and twigs introduced into the still with the leaves, the latter producing the highest yield of oil. The use of this oil is very general, and it is employed chiefly as a therapeutic agent. From 70 to 90 per cent of the oil consists of eucalyptol or cineol, the chief constituent and the one to which its valuable antiseptic properties are due.

The waste leaves and branches accumulating when the trees are cut for lumber or wood are not fully utilized. At points where a considerable number of trees are being felled a distilling apparatus could under favorable circumstances be profitably installed and successfully operated at a very moderate expense. It has been estimated that 2 tons of leaves and twigs will produce from 3 to 4 gallons of oil at a cost of about $3 a gallon for distilling the oil.[a]

MONARDAS.

Two additional plants possessing volatile oils of antiseptic value and growing wild in the whole north-central portion of the United States, from Pennsylvania to Minnesota, are wild bergamot (*Monarda fistulosa*) and horsemint (*Monarda punctata*), belonging to the Labiate tribe. These plants yield oils rich in antiseptic constituents, the former producing an oil consisting chiefly of the liquid phenol carvacrol, while the oil from the latter consists for the most part of the crystalline phenol thymol. Both of these constituents are isomeric in character and of equal value as antiseptics, the extensive use of thymol for medicinal purposes being familiar to most people.

Wild bergamot and horsemint, owing to their hardiness, are capable of profitable cultivation in the North-Central States, where the climatic conditions seem to be especially suitable for their growth and for the production of oil. The whole fresh plant during its flowering condition is generally distilled, the amount of oil obtained being influenced by conditions of growth and culture, but averaging from three-tenths to 1 per cent or more. The perennial nature of the plants enables the grower to produce them from year to year with a minimum of labor on somewhat sandy, dry soil which possibly has no great value for the production of other crops.

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[a] Bulletin 196, California Agricultural Experiment Station, p. 34.

PENNYROYAL.

Pennyroyal is a small annual herb characteristic of the east-central portion of the United States. It is distilled for its oil principally in Ohio and North Carolina, with smaller operations in intermediate States. The pennyroyal plant (*Hedeoma pulegoides*) is native to the United States, is readily propagated and grown, and yields a volatile oil which finds extensive application in therapeutics. The yield of oil distilled from the fresh flowering herb varies from three-fifths to 1 per cent.

MISCELLANEOUS AROMATIC PLANTS CAPABLE OF CULTIVATION.

The foregoing instances represent typical cases of wild plants indigenous to the United States and capable of yielding volatile oils, some of which are distilled on a quasi-commercial basis while others are not grown or distilled at all.

Hosts of other wild aromatic plants are found growing in all sections of the country, many possessing exceedingly fine fragrance and many, on the other hand, possessing odors less attractive but nevertheless possibly of value. These odorous plants will in most cases produce volatile oils which may contain constituents of value, not only in the perfumery trade but also in the arts and medicine. A systematic canvass of the flora of the United States, with special attention to those plants which possess an aroma, and a trial distillation of the same, followed by a careful, detailed chemical examination of the oils, will no doubt bring to light new oils, the value of which may be determined from the nature of the constituents identified in them. Several new volatile oils have been distilled within the past year which have been shown by chemical analysis to contain highly valuable constituents. The results of these experiments, which have proved very gratifying, will be published in the near future, and the significance of the exploration in this field of research will be clearly indicated. Practically no progress has been made in this direction within the last few decades. The necessity of these investigations is therefore strongly recommended.

Various other plants deserving mention, besides those already cultivated and those growing wild which possess volatile products of value to the perfumer and confectioner, are the rose, lavender, rose geranium, rosemary, thyme, sweet basil, summer savory, and sweet marjoram, and the umbelliferous seeds (caraway, anise, fennel, and coriander), besides the citrus fruits lemon and orange. The plants of the first general class, though not native to this country, have been introduced and grown as garden plants, luxuriant growth and excellent aromas usually being obtained.

The umbelliferous plants mentioned have also been largely grown, although only on a garden scale, usually for their seeds, which possess considerable value to the housewife and to the confectioner for flavoring or condimental purposes. The distillation of the oils from these seeds has been very largely for experimental purposes only.

The citrus fruits, although grown very extensively, have received but slight attention in the United States from the standpoint of their volatile oils, which are of so much value to the scenter and perfumer.

The rose, lavender, and rose geranium, although possessing exceedingly fragrant volatile oils have received only trifling consideration as regards cultivation for the aroma.

It is not unlikely that certain sections of the United States are adapted to the growth of the Bulgarian rose, which produces the rose oil of commerce. In order to locate these desirable regions, practical tests would be required, attention being paid to the quality of the perfume obtained and also to the labor required in the gathering of the rose petals. Besides the usual variety of rose used for perfume cultivation, the *Rosa damascena*, there are a number of other species which have become naturalized in this country and which possess fragrance of exceedingly high quality, besides being prolific bearers.

Experiments in connection with the growing of roses for perfumery purposes are worthy of attention in some of the southern portions of the United States where the conditions of climate are especially favorable and where, since the petals must be plucked by hand for distillation, labor would be sufficiently cheap to insure a certain degree of success.

Lavender (*Lavandula vera*), now grown extensively in the semimountainous districts of France and in England for the volatile oil, is no less capable of growth on the soils of this country than other plants which are at present grown profitably. The regions of growth in France, Italy, and England are not entirely dissimilar and do not possess any more suitable climatic and soil conditions than might be supplied in some sections of the United States. In this case experiments would also be necessary to locate desirable regions, but the labor factor would be minimized considerably owing to the fact that the entire tops of the plants are distilled. Owing to the little labor required in connection with lavender, enterprise in this matter should not be lacking.

The rose geranium (*Pelargonium odoratissimum*), a plant with an exquisite odor grown and distilled in France, Spain, Algiers, and the island of Reunion, deserves some consideration with regard to cultivation, inasmuch as the oil distilled from the plant is of such a nature as to make it almost indispensable in the perfumery industry. Unlike that of lavender, the odor of the rose geranium resides in the leaves, the flowers being almost odorless. Experiments in a preliminary way are now being carried on to determine the quality of the oil capable of being distilled from this plant. As in the case of the rose and lavender, the most suitable location can be learned only by a system of tests in localities with different climatic and soil conditions.

Rosemary (*Rosmarinus officinalis*), thyme (*Thymus vulgaris*), sweet basil (*Ocimum basilicum*), summer savory (*Satureja hortensis*), and sweet marjoram (*Origanum marjorana*), besides others of this type originating in Mediterranean countries and yielding oils of excellent fragrance for both the perfumers and the toilet-preparation manufacturers, can by proper attention and perseverance no doubt be produced advantageously. A factor of considerable import in the growth and distillation of these plants is that whole fresh herbs can be distilled, thus obviating the necessity of picking the flowers by hand.

The distillation of oil from such seeds as caraway, anise, fennel, and coriander, which are so universally used for flavoring and scenting purposes, has been successfully exploited in southern Europe for decades. These seeds have been introduced into the United States and grown in small quantities, principally for household use. The ease of production as a household necessity should be sufficient stimulus for growing the plants on a broader basis for the distillation of the very fragrant oils. The North-Central States, with their excellent soil and climate, undoubtedly are capable of producing profitable yields of seeds giving from 2 to 7 per cent of volatile oil. The method of distillation is similar to that of leaves or herbs, with the exception that, in order to facilitate the permeation of the steam, the seeds are ground coarsely before being subjected to the steam vapors.

The commercial isolation of oils from citrus fruits and their by-products centers principally in Sicily and Italy. The production of oil from either lemon or orange peel in the citrus regions of California has received but slight attention and should be deserving of more, inasmuch as the demand for these oils is very constant and the prices reasonably high. The distillation of waste lemons or unsalable lemons would possibly yield a volatile oil of lemon of fair quality, which no doubt would find a ready market. The Sicilian methods of hand expression are practically out of the question because of the labor factor involved. The distillation of lemon-tree prunings yields an oil of extremely high citral content, which should prove valuable for flavoring purposes.

COMMERCIAL ASPECT OF THE INDUSTRY.

VALUE AND CONSUMPTION OF VOLATILE OILS.

Mention has already been made of the value in general of volatile oils as industrial products, which commercially have not been manufactured in the United States to any extent, the mint oils being singular exceptions. Lack of interest in the growth and development of perfumery plants is principally responsible for the inactive condition now existing in this important phase of industrial enterprise. Possibly a lack of experience with regard to the growth of the plants concerned and the methods necessary for success has been largely instrumental in preventing the upbuilding of this branch of industry.

It must be conceded that very large quantities of volatile oils are at present consumed in the United States in the several uses to which they are applied. In the manufacture of perfumes the rôle played by volatile oils is all important. A large proportion of the amounts consumed enters the channels of the perfumery trade. Usually perfumes consist of blends of odors brought about by a skillful combining of several oils in varying proportions through a medium capable of holding in solution these oils and odoriferous ingredients. The manufacture of perfumes has shown but little development in the New World. Perfumery products are largely imported in the prepared condition, chiefly from France, where the skillful art of compounding has been scientifically developed.

The use of volatile oils in flavoring and in the manufacture of flavoring extracts is very extensive, but it is restricted to a comparatively small number of oils, principal among which are lemon, orange, wintergreen, peppermint, and others of this type.

For scenting purposes, such as aromatizing soaps and toilet preparations in general, volatile oils have been employed very extensively in the United States. Their use in this line of application has increased with the increase in the manufacture of these much-demanded articles.

On the other hand, the medicinal value of certain oils and of certain constituents which can be isolated from them has created a demand which in part has been supplied by home production and in part by foreign production. The separation of important therapeutic ingredients, chiefly antiseptics, has been highly serviceable in the treatment of many ailments, a striking instance of this kind being the separation of camphor from the oil of camphor, this ingredient playing an important rôle in medicine as well as in the arts. Other oils deserving mention in this connection are those of eucalyptus and thyme, the former yielding the valuable eucalyptol and the latter thymol. Another example is peppermint oil, from which menthol is isolated. All of these constituents possess therapeutic value of no little importance.

In order that the grower may become acquainted with the approximate value of volatile oils on the American market, the following tabulation of prices has been prepared. The perfumery articles listed include the principal volatile oils which enter the markets of the United States for consumption, the prices being current wholesale quotations in effect in January, 1910. Prices are per pound unless otherwise stated.

Wholesale prices of various volatile oils in the markets of the United States, January, 1910.[a]

Almond, bitter	$3.25	to	$4.75
Anise	1.10	to	1.12½
Bay	1.90	to	2.00
Bergamot	3.75	to	4.00
Cade	.16	to	.20
Cajeput	.52½	to	.55
Camphor	.09	to	.10
Caraway seed	1.15	to	1.25
Cedar, leaf	.42½	to	.45
Cedar, wood	.16	to	.17
Cinnamon	6.50	to	12.00
Citronella	.25	to	.28
Cloves	.70	to	.72½
Copaiba	1.00	to	1.10
Coriander	5.00	to	6.00
Cubeb	3.00	to	3.25
Erigeron	1.50	to	1.60
Eucalyptus, American	.35	to	.60
Fennel seed	1.10	to	1.30
Geranium, rose, African	3.50	to	4.00
Geranium, rose, Turkish	2.25	to	2.50
Ginger	4.00	to	4.50
Ginger grass	1.10	to	1.35
Hemlock	.45	to	.50
Juniper, berries	.80	to	1.00
Juniper, wood	.23	to	.25
Lavender, flowers	1.85	to	2.25
Lavender, spike	.60	to	1.10
Lemon	.77½	to	.85
Lemon grass	.80	to	.85
Lime, expressed	1.75	to	2.00
Lime, distilled	.55	to	.60
Linaloe	2.80	to	2.85
Mace	.70	to	.75
Male fern	1.90	to	2.20
Mustard	3.00	to	4.00
Neroli, petals	50.00	to	75.00
Neroli, bigard	35.00	to	50.00

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[a] Oil, Paint, and Drug Reporter, vol. 77, no. 4, January 24, 1910, p. 32.

Nutmeg	$0.70 to $0.80
Orange, bitter	2.25 to 2.35
Orange, sweet	2.20 to 2.40
Origanum	.20 to .40
Patchouli	4.00 to 4.25
Pennyroyal	1.70 to 1.80
Pennyroyal, French	1.40 to 1.50
Peppermint, tins	2.00 to 2.10
Peppermint, bottles	2.30 to 2.35
Petit grain, French	5.00 to 6.00
Petit grain, South American	2.40 to 2.75
Pimento	1.90 to 2.25
Rose, natural per oz	5.00 to 5.50
Rosemary flowers	.67½ to .75
Safrol	.40
Sandalwood	3.00 to 3.25
Sassafras	.55 to .65
Savine	1.25 to 1.30
Spearmint	1.75 to 1.85
Spruce	.40 to .45
Tansy	2.50 to 2.75
Thyme	1.00 to 1.10
Wintergreen (or sweet birch)	1.45 to 1.75
Wintergreen, leaf	3.25 to 4.25
Wormseed	1.50 to 1.60
Wormwood	6.25 to 6.50
Ylang-ylang	47.00 to 65.00

IMPORTS AND EXPORTS OF VOLATILE OILS.

Importations of volatile oils and allied products have increased from year to year until at the present time the expenditures for volatile oils and perfumes aggregate more than $2,000,000 annually.

According to the statistics of imports compiled by the Bureau of Statistics of the Department of Commerce and Labor, the importation of volatile and distilled oils, free and dutiable, for the year ending June 30, 1908, amounted to $3,619,161.33.[a] From this amount there should be deducted $886,923, which represents distilled oils not of plant origin. The total importation, therefore, of volatile oils, free and dutiable, distilled from plants for the above year was valued at $2,732,238.33. These figures represent only the volatile oils imported.

In addition to the sum mentioned, the imports of alcoholic perfumery, including toilet and cologne waters and alcoholic handkerchief perfumes, must be considered. The total imports of this class of perfumes for the year ending June 30, 1908, amounted to $184,198.13.[a]

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[a] Commerce and Navigation of the United States, 1908, p. 917.

The value of toilet preparations, such as cosmetics, hair washes, dentrifices, pastes, pomades, and powders, into which perfumery substances enter may also be mentioned in this connection. The imports of these preparations for the above year reached a total of $604,258.09.[a]

For purposes of comparison and to illustrate the remarkable increase of consumption of volatile oils of foreign production, the statistics extending over several years are tabulated.[b]

TABLE III.—*Imports of volatile and distilled oils for the years ending June 30, 1903 to 1908, inclusive.*

Free imports from—	1903.	1904.	1905.	1906.	1907.	1908.
Europe	$1,253,360	$1,318,606	$1,387,268	$1,617,796	$2,227,530	$2,215,265
North America	2,747	1,315	16,389	5,713	2,431	5,996
South America	2.364	4,052	2,205	750	4,969	14,886
Asia	191,730	252,729	176,563	308,781	407,008	314,688
Oceania	129					
Africa		290	24		304	
	1,450,330	1,576,992	1,582,449	1,933,040	2,642,242	2,550,835

TABLE IV.—*Imports of volatile and distilled oils for the years ending June 30, 1903 to 1908, inclusive.*

Dutiable imports from—	1903.	1904.	1905.	1906.	1907.	1908.
Europe	$590,493	$745,013	$865,008	$850,989	$987,919	$1,028,630
North America	14,444	12,210	4,994	12,794	18,879	15,678
South America				15		415
Asia	86,768	41,214	54,296	38,361	32,572	22,441
Oceania	14,296	20,958	24,343	15,529	17,123	19,308
Africa		361	3,003	12,227	3,485	8,134
Total	706,001	819,756	951,644	929,915	1,059,978	1,094,606

The steady increase in the importation of perfumery products, as shown in Tables III and IV, indicates that the consumption of volatile oils and scenting materials in America is also increasing. With the exception of peppermint, comparatively small quantities of crude oils are distilled and exported from the United States. The exports of peppermint oil, distilled largely in New York and Michigan, for the year ending June 30, 1908, were 141,617 pounds, valued at $357,555,[c] while all other essential oils exported amounted to $214,765.

The imports of volatile oils and perfumery materials far exceed the exports of the same products, the principal product of export being peppermint oil, a singular case where the distillation approaches industrial size in the United States.

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[a] Commerce and Navigation of the United States, 1908, p. 919.

[b] Commerce and Navigation of the United States, 1908, p. 279.

[c] Commerce and Navigation of the United States, 1908, p. 636.

The total yearly outlay for the crude materials, and also for the finished products, is sufficient to attract attention and is deserving of concerted action on the part of growers and others who might profitably engage in this neglected field of research and practice.

PRESENT SOURCES AND COST OF PRODUCTION OF VOLATILE OILS.

The present source of these commercial products, which may be gleaned from the tabulation, is Europe, from whence they are imported both in the crude state and in the manufactured condition. Italy possibly furnishes the smallest quota of volatile oils and the largest valuation, the products being chiefly the citrus oils, supplied solely by Sicily and Italy and consumed to a great extent in the United States. From France the large proportion of perfumery extracts and finer essential oils is imported, while Germany, Turkey, and Great Britain distribute to this country large consignments of crude and purified volatile oils.

The Mediterranean regions of Europe are the chief sources of these aromatics, which are so generally employed in the industries in diverse ways. The cost of production is minimized in these countries because of the cheaper class of labor as compared with labor in America, for instance. In the handling of many flowers and plants, much hand labor is required, especially in the collection of the material prior to distillation. The actual distillation and purification of the oils can be conducted with equal economy in the United States, while in the case of no small number of plants which may be suitably collected and distilled in the whole condition the question of labor becomes a less serious factor, especially in some instances where mowing machines may be employed advantageously to harvest the crops. Where hand picking is required, as in the case of some of the more delicate odors from flowers and flowering tops, cultivation and extraction of the odor could possibly be carried out in the Southern States, which have abundant sunshine, an important prerequisite in odor development. Furthermore, the labor conditions in the Southern States are such that the cost of gathering, which is a serious obstacle, would be comparable to a degree with that in foreign countries

CONCLUSIONS.

In view of the success which has been achieved in the United States along a number of special lines, the outlook for a very considerable extension of the volatile-oil industry in general seems promising. Favorable conditions of soil and climate seem to be obtainable. With an increased practical knowledge of how to handle the crops of greatest promise and with a working familiarity with the forms of apparatus used in separating the oils, the preliminary steps leading to such an extension will have been taken. Before a full-fledged industry can be expected to appear, however, much preliminary experimental work must be done over a wide area in order to ascertain the most successful combinations of soil, climate, and labor conditions.

From the standpoint of the consumption of products derived from volatile oils obtained from plants, the commercial statistics show a large and active market. They also show that the demand is now supplied in very large part from foreign sources, and an active interest in testing the possibilities of our land is suggested.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 196.

B. T. GALLOWAY, *Chief of Bureau.*

BREEDING DROUGHT-RESISTANT FORAGE PLANTS FOR THE GREAT PLAINS AREA.

BY

ARTHUR C. DILLMAN,

ASSISTANT PHYSIOLOGIST, ALKALI AND DROUGHT RESISTANT PLANT-BREEDING INVESTIGATIONS.

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SCIENTIFIC STAFF.

T. H. Kearney, *Physiologist in Charge.*
H. L. Shantz, *Physiologist.*
A. C. Dillman, *Assistant Physiologist.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 16, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 196 of the series of this Bureau the accompanying manuscript entitled "Breeding Drought-Resistant Forage Plants for the Great Plains Area," by Mr. Arthur C. Dillman, Assistant Physiologist in Alkali and Drought Resistant Plant-Breeding Investigations, Bureau of Plant Industry.

In the Great Plains area, where the rainfall is limited in quantity and is of uncertain distribution, drought-resistant varieties of crop plants are indispensable if farming is to be made a reasonably safe enterprise. Forage plants which can be successfully grown with a limited moisture supply are especially needed in order to build up a well-balanced type of dry-land agriculture. The Department of Agriculture has introduced from foreign countries many varieties that are more drought resistant than those ordinarily grown in the United States, but even these can be further improved and adapted by the use of plant-breeding methods.

The present paper describes the preliminary results of work along this line which was begun by the Bureau of Plant Industry in cooperation with the South Dakota Agricultural Experiment Station in 1906, and is now being carried on by the Bureau on the experiment farms at Bellefourche, S. Dak., and Akron, Colo. The progress that has been made in breeding drought-resistant and otherwise improved strains of alfalfa, amber sorgo, millets, *Bromus inermis*, and other forage plants especially adapted to the area is here reported. In several of these crops new and promising strains have been developed. As soon as a satisfactory test of their comparative drought resistance can be had, the seed of those strains which stand the test most successfully will be increased and distributed. It is believed that this bulletin will be useful, not only because it points out the scope of the work conducted by the Bureau of Plant Industry in this field, but because it describes simple breeding methods which can be applied by the farmers of the area for the improvement of their crop varieties in respect to drought resistance and other qualities.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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BREEDING DROUGHT-RESISTANT FORAGE PLANTS FOR THE GREAT PLAINS AREA.

INTRODUCTION.

This paper describes the results so far attained in breeding improved strains of alfalfa, sorgo, millet, smooth brome-grass, and other forage plants adapted to the semiarid conditions of the elevated region lying between the ninety-eighth meridian and the Rocky Mountains. While the work with none of these crop plants has reached completion, it is considered desirable to publish at this time a description of the objects, methods, and preliminary results.

In this plant-breeding work, as in all other investigations bearing upon dry-land agriculture that are carried on by the Bureau of Plant Industry, it is intended to make the results applicable to the whole territory in which similar climatic conditions exist. By conducting the work simultaneously and with the same methods at different stations, comparable results are expected. The working out of this plan should afford a much safer basis for the establishment of broad principles in drought-resistance breeding than could be attained by any strictly local work. Although the actual breeding is at present confined to only two of the dry-land stations, these are representative of a considerable portion of the Great Plains.

At both of these stations the Office of Forage-Crop Investigations is engaged in testing varieties of the forage plants that are believed to be adapted to the climatic conditions of the region. The drought-resistant plant breeding is conducted in cooperation with these variety tests, which not only afford material for the selection of resistant individuals, but give an excellent opportunity for comparing the drought resistance of the new strains developed with that of a large number of existing varieties of the same crops.

OBJECTS SOUGHT.

To make dry-land farming in a semiarid region like the Great Plains a reasonably safe enterprise, drought-resistant crops must be grown. Most of the varieties of crop plants that have heretofore been used in this region have originated in countries of abundant rainfall, like the eastern United States and western Europe. In recent years the Department of Agriculture has introduced a large number of more or less drought-resistant crop plants from foreign countries where the climatic conditions more nearly resemble those of the Great Plains area. Even with these plants, however, preliminary tests show that there is much opportunity for breeding work to improve the quality, increase the yield, and eliminate the less hardy and less drought-resistant individuals.

Cultivated forage plants are greatly needed in the Great Plains area. Until recently this was essentially a stock-raising territory, and although large parts of it are now being divided up into small farms devoted to grains and other crops, it seems altogether likely that stock raising will continue to be one of the chief industries. In the past the chief dependence of the stock grower has been the "range;" in other words, the native growth of prairie grasses. Only scattered attempts have been made to grow cultivated forage plants, but as the region becomes more and more settled there will be an increasing demand for hay and other stock feeds to supplement the wild-grass pasturage. The growing of forage plants is likely to become one of the most important phases of Great Plains agriculture.

The chief limiting factor in the production of crops in this region is the lack of sufficient moisture. One means of meeting this deficiency is the use of tillage methods that will conserve water in the soil, preventing as far as possible loss by evaporation. Another means of attacking the problem is to grow the most drought-resistant varieties that can be obtained. The investigations described in the present bulletin are concerned with developing such varieties by breeding methods.

The principal factors that enter into drought resistance are probably the ability of the plant to develop a root system that will utilize to the utmost a scanty supply of soil moisture and its ability to reduce transpiration, or loss of water, through the leaves and stems when the air is very dry. It is evident that certain species and varieties of crop plants are better equipped in these respects than others, since they wilt less rapidly when the soil moisture is deficient and when hot, dry winds are blowing. Every farmer on the Great Plains knows that under such conditions the sorgos, kafirs, and milos, for example, will remain fresh and green longer than corn; moreover, within the limits of a single crop species there are great differences in drought resistance, some varieties being superior to others. This has been abundantly proved in the course of the variety-testing work of the Office of Grain Investigations and of the state experiment stations, which have shown certain varieties of wheat, oats, barley, etc., to be more drought resistant than others. Finally, every close observer will notice that some individual plants of a variety are markedly more resistant than other plants from the same lot of seed growing beside them. This fact gives the plant breeder an opportunity to produce still more resistant strains of the drought-resistant varieties by the persistent selection of such individual plants.

Other qualities of the plant must not be neglected in breeding forage plants for drought resistance. The quantity and quality of the hay and seed are equally important. The individual plants which are actually most drought resistant may be deficient in yield and quality and will have to be discarded in favor of other individuals of somewhat less drought resistance but in other respects superior. Good seed production is essential not only in species that are grown primarily for the seed, but in those which are grown for hay, since in order to keep the variety drought resistant it is necessary that the seed should be produced in the region to which it is adapted. Fortunately the yield and quality of the seed are generally better in semiarid than in humid regions. This is notably the case with alfalfa, of which most of the commercial seed at present grown in the United States is produced under irrigation and consequently is not the best adapted to dry-land agriculture.

In perennial plants like alfalfa and the principal meadow grasses, hardiness or resistance to winterkilling is another essential characteristic, especially in the northern part of the Great Plains. Early maturity is of great importance in the growth of annual crops. One-half of the annual precipitation in this region occurs from April to July, inclusive. It is therefore desirable to obtain early-maturing strains which will make most of their growth during the period when the soil contains its greatest amount of moisture. In the northern part of the Great Plains the development of locally adapted varieties of sorgos, milos, and other late-maturing crops is hindered by the shortness of the season. In breeding these plants the ability to ripen seed as early as possible is a characteristic that can not be overlooked.

HISTORY OF THE INVESTIGATIONS.

The plant breeding for drought resistance described in this paper is a continuation of the work begun by Prof. W. A. Wheeler in 1904 at the Highmore substation of the South Dakota Agricultural Experiment Station. Professor Wheeler was at that time botanist of the South Dakota station. The writer was associated with him as student assistant in botany and was in close touch, almost from the beginning, with the plant-breeding work carried on under his direction. In the breeding work at Highmore all the principal forage crops of the region were taken up, alfalfa, clover, millet, sorghum, smooth brome-grass (*Bromus inermis*), western wheat-grass (*Agro-*

pyron smithii), and other species. At the outset, variety tests were made with seed obtained from all available sources. More than twenty different varieties of alfalfa, various species of grasses, strains of clover, and varieties of foxtail millet were tested side by side. Numerous individual plant selections were made from the varieties of these crops that proved to be most drought resistant and otherwise valuable.[a]

STATIONS WHERE WORK IS NOW IN PROGRESS.

INCEPTION OF THE WORK.

The Bureau of Plant Industry in 1906 undertook cooperation in the breeding work at Highmore substation, South Dakota, Mr. T. H. Kearney being in charge of the work on the part of the Bureau. In 1907 Professor Wheeler resigned his position as botanist of the South Dakota Agricultural Experiment Station. In May, 1908, cooperation in forage-plant breeding between the Bureau and the South Dakota Agricultural Experiment Station was discontinued and the work of this office was transferred to the experiment farm which is conducted by the Bureau of Plant Industry in cooperation with the project of the United States Reclamation Service, at Bellefourche, S. Dak. Work was begun at Bellefourche with about forty selections of alfalfa, a strain of amber sorgo, and a strain of smooth bromegrass, all of which had been found promising at Highmore. Part of the breeding work at Bellefourche is carried on in cooperation with the variety testing conducted at that station by the Office of Forage-Crop Investigations of the Bureau of Plant Industry.

In 1908 breeding work was also begun at the Akron (Colo.) Dry-Land Station of the Office of Dry-Land Agriculture Investigations, starting with varieties and strains of forage plants that had previously given good results at Highmore and at Bellefourche.

BELLEFOURCHE EXPERIMENT FARM.

The Bellefourche Experiment Farm is conducted by the Office of Western Agricultural Extension,[b] Bureau of Plant Industry, on the Bellefourche project of the United States Reclamation Service in South Dakota. It is located 20 miles east and 4 miles north of the town of Bellefourche. An irrigation canal has been planned to extend through the farm, dividing it into two nearly equal parts. It is on land lying above this projected canal that the drought-resistant breeding is carried on. On part of the land (about 40 acres) the native sod was broken in June, 1907, and this part has been kept under thorough cultivation since that time. Another field of 20 acres was broken in 1908 and a third, of 10 acres, in 1909.

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[a] The preliminary results of this work were reported by Prof. W. A. Wheeler in Bulletin 101, of the South Dakota Agricultural Experiment Station, published in March, 1907.

[b] During the first year when this breeding work was carried on at Bellefourche the experiment farm was under the direction of the Office of Dry-Land Agriculture Investigations.

The soil conditions here are different from those existing in the greater part of the Great Plains region, the Bellefourche soil being a heavy clay of the Pierre shale formation locally known as "gumbo." This formation underlies nearly the entire State of South Dakota, but it is covered by other formations except in the west-central part of the State. There it constitutes the surface soil of practically the entire area between the Missouri River and the Black Hills. It forms a broad semicircle east of the Black Hills, in South Dakota, and extends northward into Montana and southward into Nebraska. The area covered in South Dakota is probably about 16,000 square miles, being more than one-fifth of the area of the State. This soil takes up water very slowly, so that during very heavy or long-continued rains there is considerable run-off. It has, however, a high capacity for absorbing water. Its moisture equivalent[a] is about 29 per cent. The soil is therefore capable of holding a large quantity of water and retains this moisture well when the surface is so cultivated as to form a protecting mulch. If the surface is not cultivated and is allowed to become dry and baked, the soil cracks badly, owing to the considerable shrinkage in drying. These cracks extend down 4 or 5 feet, allowing the subsoil to dry out. This is often the condition of the fields during the winter and is probably one of the factors which makes winterkilling of alfalfa common in this region. The fine roots of the plants are evidently torn severely in the shrinking of the soil. The large cracks about the plant promote drying of the roots and permit extensive and severe freezing. It is the opinion of the writer that this extreme winter drought in the alfalfa fields has as much to do with the killing of alfalfa plants as the mere fact of low temperature.

The average annual precipitation at the station probably does not exceed 15 inches. At Ashcroft, S. Dak., which is about 65 miles northwest of the Bellefourche Experiment Farm, the average annual precipitation during the seventeen-year period from 1892 to 1909 was 14.2 inches. The average seasonal precipitation, April to August, inclusive, was slightly over 9 inches. At the Bellefourche station records of the seasonal (April to August) rainfall have been kept for only two years. The totals are as follows: 1908, 8.6 inches; 1909,

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[a] As defined by Briggs and McLane in Bulletin 45, Bureau of Soils, U. S. Department of Agriculture, this term indicates the percentage of moisture to dry weight of soil that remains after a centrifugal force equivalent to 1,000 times gravity has been applied to the saturated soil.

13.3 inches. The greater part of the rainfall in this region occurs during the early growing season, and the latter part of the summer is liable to be exceedingly dry.

Although the soil type at Bellefourche is peculiar to only a part of the region, the similarity of the climatic conditions is such that we may expect that strains of forage crops developed at this station will be adapted to the greater part of western North and South Dakota and eastern Montana.[a]

AKRON DRY-LAND STATION.

The Akron Dry-Land Station is conducted by the Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry. The farm is located about 4 miles east of Akron, Washington County, in northeastern Colorado. It was selected as a desirable place for breeding drought-resistant forage crops because of its central location in the Great Plains. The climatic conditions are probably more severe here than in the greater part of the central Great Plains, but in general the station is representative of a large part of the area. The altitude of the station is nearly 4,700 feet, being about 1,800 feet higher than the Bellefourche station. The average annual precipitation, as computed from the records at several places in eastern Colorado, is about 17 inches, though the precipitation at Akron for the past few years has slightly exceeded this.

The land at the Akron station, on which the plant-breeding nursery is located, was broken from the native sod in June, 1907, and has been under cultivation ever since. The soil may be classed as a loam, and is generally favorable for the production of crops when sufficient moisture is present. The soil is typical of the "hard lands" of the Great Plains, as distinguished from the "sand lands" of eastern Colorado, western Nebraska, and other sections of this region. The moisture equivalent of the Akron soil is about 17 per cent, which indicates that it is only medium in water-storing capacity.

ALFALFA BREEDING FOR DROUGHT RESISTANCE.

ALFALFA BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM.

SEGREGATION OF STRAINS.

In the alfalfa breeding at Bellefourche, while increased drought resistance has been the principal object in view, it has been necessary also to take into consideration hardiness, seed production, and the yield and quality of the forage. All selections have been made with the idea of combining large forage and seed production in the same individual plant, the forage type, however, receiving first consideration. A thorough test of the yields of all strains developed is made in broadcast plats and in cultivated rows. It should be said that no proper test of drought resistance has been had in the alfalfa-breeding work up to this time. During the time the work was carried on at Highmore, from 1905 to 1907, inclusive, the annual rainfall was above the average for that station. The season of 1908 at Bellefourche was a dry one, but this was the year when the breeding work was begun there and the plants were too young to afford records of yields under dry conditions. But since the first season's growth of an alfalfa plant is a critical period in its life, and since these selections made a good growth at Bellefourche in the comparatively dry year, 1908, it would seem that they must be at least fairly drought resistant.

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[a] In transferring the breeding work from Highmore to Bellefourche, the crops were placed under different conditions of soil and a slightly different climate. The soil at the Highmore substation is a glacially deposited clay loam, containing some sand. The altitude is a little less than 1,700 feet, as compared with 2,900 feet at the Bellefourche station, and the precipitation is about 17 or 18 inches annually. Highmore may be considered as located near the eastern edge of the Great Plains, while Bellefourche is representative of the more arid portion of the northern Great Plains.

During the season of 1909 the precipitation was again above the average, so that no test of drought resistance was secured that year. It will therefore be necessary to retain all of the progeny rows and plats until a proper test of drought resistance is secured.

The alfalfa stocks used in the breeding work at Bellefourche consisted of selections from six strains which were grown at the Highmore (S. Dak.) substation. Two of these strains, South Dakota No. 162 and No. 164, are recommended by Prof. W. A. Wheeler in Bulletin 101 of the South Dakota Agricultural Experiment Station as the best of the stocks tested at Highmore. The twenty stocks tested there included several hardy stocks imported by the Department of Agriculture previous to the year 1905. The two best varieties, which are described on a later page of this bulletin, proved to be perfectly hardy and of good forage and seed producing ability. Four other stocks tested at Highmore, which proved fairly hardy, are also represented in the breeding plats at Bellefourche. In the following discussion each strain is designated by a letter, the selections made from each strain being numbered in consecutive order; as A–1, E–12, etc.

Strain A.—This is South Dakota No. 65. The seed was screened from a lot of durum wheat imported from Tashkend, Turkestan, in 1902, by the United States Department of Agriculture. It was planted in 1902 on a small plat, about 12 by 50 feet, at Brookings, S. Dak. This plat went through four seasons there (from the spring of 1902 to the fall of 1906), and did not suffer any from winterkilling.

"Seed from this plat [harvested in 1904] was planted at the Highmore substation, in 1905, in a selection row. A few of the plants in this row died during the winter of 1905–6, showing that it is not perfectly hardy under severe test."[a] The plants now growing at Bellefourche represent the fourth generation of seed. They are somewhat coarse, with stems inclined to be stout and not greatly branched. The results obtained this season indicate that this strain is fair in seed production.

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[a] Wheeler, W. A. Bulletin 101, South Dakota Agricultural Experiment Station, p. 135.

Strain B.—This is South Dakota No. 66. "The seed was obtained by Prof. N. E. Hansen, from Merke (lat. 43° N., long. 73° E.), northern Turkestan in 1898 for the United States Department of Agriculture. It was distributed by the department as S. P. I.[a] No. 1169. It was sown in a small plat at Brookings in 1899 and has not winterkilled to date. The seed from this plat was sown at Highmore in 1905 in selection rows. The results seem to show it to be about equal to No. 65 in quality, hardiness, and seed production."[b] The plants of this variety are large, coarse, woody in texture, and poor in amount of branching. It has proved the poorest in seed yield of any of the varieties tested at Bellefourche.

Strain C.—This is South Dakota No. 67. "The seed was obtained from the Minnesota experiment station as Minnesota No. 3 in 1902."[b] Minnesota No. 3 was derived from seed purchased by the Minnesota experiment station from a commercial seed firm under the name of "Grimm" alfalfa, but has shown itself to be different from that variety in hardiness and other qualities. It is similar in type of plant to strain E described below, but is somewhat inferior in both forage and seed yield.

Strain D.—This is South Dakota No. 150, purchased from a seed firm as Turkestan alfalfa. It is similar in type of plant to the other Turkestan strains, which are inclined to be woody, spreading, and lacking in leafiness and branching.

Strain E.—This is South Dakota No. 162. This strain originated from the Grimm alfalfa which has been grown near Excelsior, Minn., for more than fifty years.[c] In all the tests at Brookings, Highmore, and Bellefourche it has proved superior to all other stocks tested in seed production, hardiness, and forage type of plant. The selections grown at Bellefourche are inclined to be very leafy, much branched, with short internodes and fine stems. This gives the maximum amount of palatable forage. The selections have proved to be uniformly good in seed production, which is a valuable characteristic of these selections, since the seed yield is one of the important features of the crop in the Great Plains region.

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[a] An abbreviation for the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture.

[b] Wheeler, W. A., loc. cit.

[c] Brand, C. J. The Acclimatization of an Alfalfa Variety in Minnesota. Science, vol. 28, 1908, p. 891. Westgate, J. M. Bulletin 169, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909. Science, vol. 30, 1909, p. 184.

Strain F.—This is South Dakota No. 164, which is thought to be S. P. I. No. 991, a Turkestan stock. This strain is less coarse and is better in quality of forage than most of the Turkestan varieties. In amount of seed produced it stands second to strain E, as noted in Table I.

A part of the selections with which the breeding work was begun at Bellefourche were made in 1907 by Mr. John Cole, now of the Office of Dry-Land Agriculture Investigations of the United States Department of Agriculture, but at that time connected with the South Dakota Agricultural Experiment Station and in charge of the Highmore substation. These are selections A 1 and 2, B 1, C 1–4, D 1 and 2, E 1–7, and F 1–3. Selections E 9–16 and F 4–12 were made at the Highmore substation in 1906 by Prof. W. A. Wheeler. Selections E 17–31 and many other selections not described in this bulletin were made by the writer.

BREEDING METHODS USED.

In the alfalfa-breeding nursery (Pl. I, fig. 1) plants are grown singly in hills 21 inches apart, the rows being 42 inches apart. This allows 75 plants to a row in the regular plats of the station, which are 8 rods long. The seed from a single plant is generally planted in one row of hills, but when sufficient seed was available, two rows of hills have been planted to a single selection, and when the quantity of seed available was small, less than a full row has been planted to a selection. Where less than a row was planted there were 25 or 50 hills instead of 75, as in a full row. The hills are planted at definite distances apart so that the rows of plants are in line in both directions. (See Pl. I, fig. 1.) Each row is given a progeny number and each plant within the row an individual number corresponding to the number of the hill in which the plant grows. If a plant is missing in the row the order of numbering is not changed, each plant in the row being permanently designated by the position it actually occupies. This system makes a convenient and certain means of designating each plant and obviates the use of stakes except at the head of the row.

At the period when the first blossoms appear the plants in the nursery are studied carefully and complete notes are taken as to the type of plant, the amount of branching, leafiness, and the color of the flowers. The forage type of plant is best judged at this time, for it is at this stage in the development of the plant that it should be cut for forage. After these notes are taken all the inferior plants, together with such as are divergent from the type of the row, are cut and removed from the nursery. This is done in order that the pollen from these inferior plants will not be carried to and fertilize the flowers of the superior plants. It may be explained further that all plants at the ends of the rows are discarded. This is done in order to secure comparable results of yields per plant from each progeny row, as the end plants, because of their favored position, make a larger growth. The purpose is to secure accurate comparative yields of all the progeny rows.

Later in the season, when the seed is ripe, the superior individuals are selected as mother plants to furnish seed for planting the following season and thus continue the work of selection.[a]

After the superior plants have been selected the bulk of the plants in the row are harvested, dried in shocks, weighed, and thrashed. Since a record is kept of the number of plants harvested, an accurate estimate of the producing power per plant of each row is easily made. The yields of the progenies grown at Bellefourche during the season of 1909, which are in the fourth generation of selection, are presented in Table I.

UNIFORMITY OF PLANTS IN THE PROGENY ROWS.

Breeding work with a plant like alfalfa has the special advantage that one is able to compare living plants belonging to different generations of selection. Alfalfa being perennial, the mother plants can be retained in their original places in the breeding nursery for comparison with their progeny. Thus, the degree in which the progeny has inherited the desirable characters of the mother plant can be checked by direct comparison. In general, there has been great uniformity in the rows although they are the progeny of plants that were selected without any precaution to insure close pollination. As shown in Table I, in 29 out of 36 progeny rows harvested separately, in which the plants "off type" were discarded, over 80 per cent of the plants in each row were harvested as uniform in type. Some prominent types may be noted, as E–2, in which the plants were very erect, rather slender, and only moderately branched, and had dark-purple flowers. This is a rather distinct, easily recognizable form and it will be noted that 84 per cent of the plants in this row conformed to the type. B–1 is another distinct type; the plants are tall, coarse, slightly branched, and woody, with very light purple flowers fading to white. Of the plants in this row 92 per cent were typical. In some progeny rows the variation in type of plant has been great, but in general the uniformity is close enough to show that this method of simple selection without isolation can give valuable results in breeding alfalfa.

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[a] Heretofore the plants have not been inclosed with screens to insure self-pollination; but it is the plan in future work to inclose a number of plants and pollinate them by hand and thus get a comparison of the uniformity of progeny of screened plants and those which are exposed in the normal way to the chance of cross-pollination by insects. These screens will be placed over the plants at the beginning of the blossoming period. Hitherto the only distinction made with superior plants has been to harvest them separately at the time the seed matured.

COMPARATIVE YIELDS[a] OF THE DIFFERENT STRAINS AND PROGENIES.

TABLE I. *Uniformity and seed yield of plants of alfalfa grown in progeny rows at Bellefourche, S. Dak., in 1909.*

Strain.	Progeny No.	Proportion of typical plants in progeny rows.	Average dry weight per plant.	Average seed yield per plant.	Seed yield per 100 grams of dry plant.
		Per cent.	*Grams.*	*Grams.*	*Grams.*
A	1	91	138	21	15.2
	2	88	129	16	12.4
B	1	92	153	12	7.8
C	1	82	150	14	9.3
	2	81	150	21	14.0
	3	79	135	16	11.9
	4	85	132	20	15.1
D	1	89	138	13	9.4
	2	85	123	17	13.8
E	1	79	171	27	15.8
	2	84	171	18	10.5
	3	72	....	23	....
	4	88	189	33	17.5
	5	80	144	23	16.0
	6	82	192	32	16.7
	7	80	150	25	16.7
	9	91	150	22	14.7
	10	90	138	22	16.0
	12	100	150	21	14.0
	13	95	138	19	13.8
	15	74	180	27	15.0
	16	83	....	28	....
	17	85	138	20	14.5
	18	66	165	28	17.0
	19	84	180	33	18.3
F	1	85	144	18	12.5
	2	76	150	20	13.3
	3	81	150	19	12.7
	5	87	135	14	10.4
	6	87	132	15	11.4
	7	91	134	22	16.4
	8	83	192	28	14.6
	9	57	144	17	11.8
	10	85	....	21	....
	11	82	144	20	13.9
	12	91	180	30	16.7

The results given in Table I were obtained from a large number of plants. Where the progeny occupied two rows of the breeding nursery the number of plants harvested in the bulk lot exceeded 100. Where the progeny occupied one row the number of plants usually exceeded 50, but where less than a row was planted the report shows the yield of only 20 to 50 plants. Yields estimated on more than 50 plants should represent fairly the producing power of the progeny under this system of planting. Column 3 of Table I shows the percentage of plants of uniform type in the progeny row, leaving out of consideration the inferior plants which were discarded early in the season.

The dry weight of the plants and the seed yield have been reduced to an average per plant so as to afford a comparison of the producing power of the progeny. Column 6 of the table gives the seed yield per 100 grams weight of plant, showing the relation between the seed yield and forage production in each progeny row. It will be seen that a large seed yield is usually associated with a large forage yield, as is shown by a comparison of columns 4 and 5. This result throws some light upon the question whether or not heavy seed production and heavy forage production are opposed, or whether they can be combined in the same individual; the results seem to indicate that these two characteristics can be combined. This purpose has, in fact, been constantly kept in mind in the selection of the mother plants.

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[a] The yields obtained in the breeding nursery, where each plant has much more space than in ordinary field culture, do not necessarily indicate that under field conditions the different strains will be found to occupy the same relation to each other in comparative yielding power.

Table II is inserted to show the comparative yields of the strains represented in the breeding work. It will be seen that strain E exceeds all others in both seed yield and forage production, as shown by the yield per plant, and that large seed yield and heavy forage production can be combined in the same strain.

TABLE II.—*Proportion of plants winterkilled and average yield of each strain represented in the alfalfa-breeding nursery at Bellefourche, S. Dak., in 1909.*

Strain.	Variety from which derived.	Winter-killing, 1908–9.	Total number of plants harvested.	Average dry weight per plant.	Average seed yield per plant.
		Per cent.		*Grams.*	*Grams.*
A	Turkestan		182	147	18
B	Do.	2	132	153	12
C	Grimm		281	141	18
D	Commercial Turkestan		121	132	14
E	Grimm	4	601	162	24
F	Turkestan	1	354	150	21

WINTERKILLING.

The winterkilling of the varieties in the breeding nursery during the winter of 1908–9 was practically negligible, while the broadcast plats and cultivated rows of the same varieties did not show any killing at all. The nursery method of planting, where each plant stands alone and unprotected, is the most severe test of hardiness. At the Ashcroft (S. Dak.) Weather Bureau station, where conditions are probably most nearly representative of the Bellefourche Experiment Farm, a temperature of −30° F. was recorded in January, 1909.

It should be said that the varieties of alfalfa represented in the breeding plats at the Bellefourche Experiment Farm have been subjected to severe winterkilling tests for several generations. They represent selections, some of three and some of four generations of individual plants grown in the breeding nursery at Highmore under conditions which eliminated the less hardy individuals. The minimum temperatures recorded during the time the work was carried on at the Highmore substation are as follows: 1904, −27° F.; 1905, −36° F.; 1906, −31° F.; 1907, −27° F. There was some winterkilling during each of these winters, especially in the breeding nursery, where the test is most severe. The winter of 1905–6 was especially severe; among 20 stocks tested at Highmore, 8 winterkilled greatly and were discarded. Some winterkilling was noted in all the varieties except South Dakota No. 162, which is strain E of the above table

FUTURE TESTING OF STRAINS.

The bulk seed from each of the best progeny rows was planted in 1910 under two conditions, in cultivated rows (Pl. I, fig. 2) and in broadcast plats. If conditions favor a test, the comparative drought resistance of the different strains, progenies, and individual plants will be carefully noted. At the beginning of the season a record of their hardiness and earliness of development was made. Later in the season comparisons of yields will be made from the broadcast plats as to forage production and from the cultivated rows as to seed production. If the progenies which have proved superior thus far continue to show superiority in these characters, combined with hardiness and drought resistance, seed from them will be increased and distributed as soon as possible.

ALFALFA BREEDING AT THE AKRON DRY-LAND STATION.

The plan followed at Bellefourche in the alfalfa-breeding work has been followed at the Akron Dry-Land Station. There is not likely to be so severe a test of hardiness or resistance to winterkilling at Akron as farther north in the Great Plains. The test of drought resistance, however, is likely to be quite as thorough.

The strains of alfalfa are the same as those used at the Bellefourche Experiment Farm. The plan has been to divide the seed of the selections made at Bellefourche and from other sources and plant part of the seed at Bellefourche and part at Akron. In this way a comparison of the effect of somewhat different climatic and soil conditions can be made and the possibility of obtaining an adequate test of drought resistance is increased. As the breeding nursery was established in 1909, no results have yet been obtained except notes on the season's growth and the autumn stand of each progeny row.

SEED PRODUCTION OF ALFALFA PLANTED IN HILLS.

Maximum seed production in alfalfa can no doubt be attained by growing plants in such a manner as to allow cultivation of the soil rather than by planting in broadcast plats. The method of planting in single or double cultivated rows has been recommended[a] and is unquestionably an improvement over the broadcast method for seed production. The results as to seed production in the breeding nursery at Bellefourche suggest that the method of planting in hills is still more favorable to seed production and may be used to good advantage where it is desired to increase rapidly the seed of some valuable strain. It was observed that the yield of seed in the breeding plats at the Highmore substation was often fairly good when the broadcast plats yielded little or no seed. In 1907 a commercial seed firm in South Dakota, with which the writer was then associated, obtained a yield at the rate of 200 pounds of seed per acre in the alfalfa-breeding nursery of half an acre. The plants were grown singly 18 inches apart, in rows 36 inches apart. In the breeding nursery at Bellefourche in 1909 the yield of seed was much greater than from alfalfa seeded in broadcast plats or in double-cultivated rows. These yields are presented in Table III.

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[a] Brand, C. J., and Westgate, J. M. Circular 24, Bureau of Plant Industry, U. S. Dept. of Agriculture.

TABLE III.—*Seed yield of alfalfa planted in hills compared with broadcast or row planting.*

Plat No.	Method of planting and variety.	Seed yield obtained on $\frac{1}{10}$-acre plat.	Yield per acre.	Yield estimated on perfect stand.
		Pounds.	*Pounds.*	*Pounds.*
67	Breeding nursery, 475 plants, strains D and F, in hills	20	200	348
69	Breeding nursery, 500 plants, strain E, in hills	26	260	430
61	Broadcast plat, strain of Grimm alfalfa	12	120	
62	Double-cultivated rows, strain of Grimm alfalfa	8½	85	

In plat 67, 325 plants, and in plat 69, 350 plants, were discarded or missing. The missing plants had been destroyed chiefly by pocket gophers. In estimating yields the living plants nearest these were discarded as having had an unduly favorable opportunity. For this reason column 4 is added, estimating the yield per acre of a perfect stand in the breeding nursery, which would be 825 plants on the $\frac{1}{10}$-acre plat.

The method of planting in hills or very thinly in single rows can be recommended only where rapid increase of seed is desired, as when some especially valuable selection is grown. With the present interest in alfalfa breeding and the great need for drought-resistant and hardy strains, the price of seed of superior strains is likely to be high. Under such conditions the above method of seed increase may be used to advantage.

BREEDING DROUGHT-RESISTANT SORGOS.

CONDITIONS TO BE MET.

Sorgo is an important forage crop in the central and southern Great Plains, but its use in the northern part of the region has been limited because the season is too short to allow the crop to mature seed. Sorgo is not likely to be planted extensively in regions where seed can not be matured. To purchase seed every year often makes the crop unprofitable. Further than this, the greatest food value of the crop can not be secured unless it reaches the point of flowering at the time of harvesting. The purpose in the breeding work described here has been to obtain a drought-resistant and productive strain which will mature early. Such a strain would extend the sorgo-growing area north of its present limits.

The breeding work with sorgo at Highmore and Bellefourche has been done with a saccharine sorghum of the Minnesota Amber type, South Dakota No. 341. This strain has slender stalks and rather long, narrow leaves. The plants stool quite freely, having from two to six suckers per plant. The seed panicles become open and spreading as the seed ripens. The seeds are reddish yellow in color when separated from the glumes. The glumes, however, are black and either smooth or slightly hairy. In thrashing, many of the seeds separate from the glumes. The stock of this variety was found at the Highmore substation in 1903 under the name of "Montana." This is all that is known about its history. It was grown at Highmore in 1906 in comparison with two other amber types and proved to be two weeks earlier than the varieties with which it was compared. The earliness of the type has made it valuable as a stock from which to work. Two valuable selections (Pl. II, fig. 1) were made in the course of the breeding work at Highmore, and seed of these has been increased and is now on the market.

The two selections referred to were very marked in point of earliness and in uniformity of the progeny. It is probable that the early flowering of the mother plant in each of these selections prevented cross-pollination from any of the surrounding plants, which were ten days or more later in flowering. This insured self-fertilization and the resulting uniformity of progeny.

Yields of sorgo, South Dakota No. 341, at the Highmore substation for three seasons, 1906 to 1908, inclusive, and at the Bellefourche station for 1908 and 1909, were furnished by the Office of Dry-Land Agriculture Investigations. These yields are from each of two $\frac{1}{10}$-acre plats used in the rotation experiments of that office and are as follows:

TABLE IV.—*Yield per acre of air-dry fodder at Highmore and Bellefourche, S. Dak.*

Place and year.	Yield of rotation No. 33.	Yield of rotation No. 34.	Average yield.
Highmore:	*Pounds.*	*Pounds.*	*Pounds.*
1906	11,140	10,810	10,975
1907[a]	4,940	5,760	5,350
1908	8,150	7,250	7,700
Bellefourche:[b]			
1908	2,330	4,200	3,265
1909	4,280	7,560	5,920
Average per acre of all plats	....	....	6,642

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[a] The low yields in 1907 at Highmore were due to a poor stand of plants in both plats.

[b] The lower yields in rotation No. 33 than in No. 34 at Bellefourche for both years, 1908 and 1909, are due to the poorer type of soil where the plats of rotation No. 33 were located. The soil there is very poor in spots, being liable to puddling and to extreme baking when dry.

The average yield of 6,642 pounds of feed per acre at these two stations is sufficient to warrant the growing of this strain where forage of this kind is desired.

SORGO BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM.

In 1908 the writer obtained some of the bulk seed of the South Dakota No. 341 stock from the Highmore substation and planted a field with it at Bellefourche for the purpose of making selections. In September, 1908, 18 individual selections were made in this field. These were selected for earliness, amount of stooling, and uniformity of the main stalk and suckers in height and ripening. The selections ranged in date of ripening from September 10 to September 20, in height from 4½ to 5½ feet, in yield of seed from 50 to 100 grams, and in number of suckers from 3 to 5 per plant. The characters which make the most desirable type of forage sorgo are slender stems, uniformity in the size of the suckers on each plant, and large total leaf surface, and these points governed the selection.

The seed of each of these selected plants was planted in a single row, 8 rods long, in 1909. In date of ripening the progeny rows were very similar to the mother plants, ranging from September 10 to September 18. In height the progenies exceeded the respective mother plants by about 6 inches, the plants ranging from 5 to 6 feet high. This was probably due to the more favorable season in 1909. Each individual row was quite uniform as to height and type. (Pl. II, fig. 2.)

In order to show what characters apart from drought resistance are regarded as most important in a sorgo for the northern Great Plains and to give some idea of the amount of diversity still remaining in this selected stock, short descriptions are given of the types that predominated in the 1909 progenies of the five most promising selections. It is possible that strains derived from more than one of these selections may ultimately be found valuable for this region. Thus, near the northern limit for sorgo culture the earliest maturing strain, even if somewhat inferior in other respects, may prove to be the most useful, while farther south a later developing strain which produces a better quality of forage may be preferred.

Selection No. 2.—Plants in this row stooled freely; the stalks were small and fine and there were many small suckers which would make forage of good quality. The progeny was good in seed production and uniform in early ripening. This was one of the best rows.

Selection No. 6.—This was a good row, but was slightly later than that of selection No. 2 in ripening seed. It was very uniform in height and type of plant. The plants were very leafy and had numerous suckers that were slender and fine.

Selection No. 9.—This was about the best row in the breeding plat; the plants stooled freely, the stalks were small, and the plants uniform in height and type. It was early and uniform in ripening seed.

Selection No. 10.—This row was very similar to that of selection No. 9 except that the plants were later in maturing and the stalks were slightly thicker. (See Pl. II, fig. 2.)

Selection No. 12.—This was a fairly good row; the stalks were small and the plants stooled freely and were early in ripening. A peculiarity of this row was that a large percentage of the outer glumes of the seed were free from hairs.

Bulk seed was saved from each of the above selections. This seed was harvested September 16, when nearly all the plants in the breeding nursery were mature. Seed from each row was harvested separately by cutting the mature panicles from all the plants that showed the type characteristic of the row. No comparisons of yields of either seed or forage were made, as the differences in stand in the different rows would have made the comparison of little value. The bulk seed from each row was planted in field plats in 1910 for comparison of their drought resistance, yield, uniformity, earliness, and other characteristics. The writer believes that sorgo can be made a valuable crop in the northern sections of the Great Plains if this early-maturing type is planted. Since no strain that will ripen seed is at present generally grown in this region, it would seem desirable to increase seed of these superior selections as rapidly as possible for distribution to farmers.

SORGO BREEDING AT THE AKRON DRY-LAND STATION.

Seed of each of the selections made at Bellefourche in 1908 was planted in single rows 8 rods long at the Akron Dry-Land Station in 1909. Each of the plants selected in 1908 bore two or more panicles of mature seed. The seed from one of these panicles was planted at Bellefourche and the seed from the other at Akron. The progeny was very similar in type of plant and general characteristics to that grown at the two stations, but it is evident that extreme earliness in ripening is not of first importance at the Akron station. The progeny of selection No. 13 was considered the best row there, while at Bellefourche it was decidedly too late in maturing and the stalks had a tendency to be coarse and pithy. This row, No. 13, was harvested for seed, and the seed was planted for comparison with other varieties in 1910.

It is probable that later maturing varieties (for example, Orange and Red Amber) may be grown to good advantage at Akron, and in future drought-resistance breeding work at that locality such varieties will be considered.

BREEDING DROUGHT-RESISTANT MILLETS.

SEGREGATION OF STRAINS.

Several varieties of foxtail millets (*Chaetochloa italica*) are grown rather extensively in the northern Great Plains. This crop is especially valuable there because it requires only a few weeks to complete its development; for this reason it is often used as a "catch crop" to replace other crops which have been frozen or otherwise destroyed in early summer.

Most of the varieties now on the market are mixtures of more or less distinct types and offer an excellent opportunity to the plant breeder to segregate these types and develop pure strains. This has been the purpose of the work here described, special attention being given to the segregation of strains characterized by drought resistance, early maturity, and maximum forage yield.

RESULTS OF PRELIMINARY WORK AT THE HIGHMORE SUBSTATION.

Mention is made in Bulletin 101 of the South Dakota Agricultural Experiment Station of the breeding work with foxtail millets carried on in cooperation with the Bureau of Plant Industry at the Highmore substation. The breeding work was conducted with five varieties of millet—Kursk, Common, Siberian, Hungarian, and German. Several uniform and productive strains were developed at Highmore and were grown for comparison of yields, but the results have not been published in detail. Seed of one pure strain of Kursk millet developed at Highmore has been increased by a commercial seed firm and is now offered for sale. The Office of Forage-Crop Investigations of the Bureau of Plant Industry secured some of this seed in 1907, and it was distributed under S. P. I. No. 22420.

VARIETY TESTS AT THE BELLEFOURCHE EXPERIMENT FARM.

In 1908 breeding work was begun at the Bellefourche Experiment Farm with five varieties of foxtail millet (*Chaetochloa italica*). In cooperation with the Office of Forage-Crop Investigations a preliminary test was made in 1908 of these varieties in $\frac{1}{20}$-acre plats and in 1909 in $\frac{1}{10}$-acre plats. The results were as follows:

TABLE V.—*Yield per acre of five varieties of foxtail millet at Bellefourche, S. Dak., in 1908 and 1909.*

Variety.	Yield of hay from plat.	Estimated yield of hay per acre.
Plats of one-twentieth acre, 1908:	*Pounds.*	*Pounds.*
S. P. I. No. 22420, Kursk	144	2,880
S. P. I. No. 22423, Common	150	3,000
S. P. I. No. 22340, German	116	2,320
S. P. I. No. 22424, Siberian	150	3,000
S. P. I. No. 22426, Hungarian	130	2,260
Plats of one-tenth acre, 1909:		
S. P. I. No. 25220, Kursk	154	1,540
S. P. I. No. 24841, Common	206	2,060
S. P. I. No. 24842, German	68	680
S. P. I. No. 24843, Siberian	194	1,940
Average yield for the two years of the three best millet varieties:		
Common		2,530
Siberian		2,470
Kursk		2,210

About thirty other species and varieties were tested in single rows in 1908, but none of these proved to be of any special value for this region except S. P. I. No. 20694. Seed of this number was obtained by Professor Hansen, at Khokand, Russian Turkestan, in 1906, when acting as agricultural explorer for the Department of Agriculture. A quantity of the seed was planted in a selection row at Bellefourche in 1908. Two plants in this row matured seed and were saved. Since the plants were identical, so far as could be seen, the seed from the two was mixed and planted in a progeny row in 1909. The selection is of good forage type, but the panicle is open and the seed shatters readily.

MILLET BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM.

BREEDING METHODS.

The methods used in the millet-breeding nursery were much the same as in the alfalfa nursery. In 1908 the seed of each of the varieties, Kursk, Common, German, Hungarian, and Siberian, was planted in hills 8 inches apart, in rows 42 inches apart (Pl. III, fig. 1). The seedlings were thinned to single plants in a hill. Selections of the superior individual plants were made and the seed planted in single rows 8 rods long, in 1909 (Pl. III, fig. 2).

RESULTS OF THE WORK.

The table following gives the record of yields and other data concerning the individual plant selections made in 1908 the progeny of which gave the largest yield in 1909:

TABLE VI.—*Yield of millet selections of 1908 and of their progenies grown at Bellefourche, S. Dak., in 1909.*

Variety and selection.	Number of selections in 1908 and of progeny rows in 1909.	Individual selections of 1908.			Progeny grown in 1909.[a]		
		Total dry weight of plant.	Weight of seed.	Proportion of seed to 100 parts of straw.	Total dry weight of plants.	Weight of seed.	Proportion of seed to 100 parts of straw.
Kursk, No. 22420:[b]		*Grams.*	*Grams.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*
1		100	29	40	28	9½	51
2		125	43	52	29½	9½	48
4		85	16	23	29	9	45
5		130	27	26	30	8½	41
8		120	19	19	28	8½	43
10		130	29	29	27	8¾	48
11		150	22	17	27	8	42
Common, No. 22423:[b]							
1		112	42	60	21	7¾	58
4		95	33	53	18¾	7¼	62
7		100	38	61	19	8	73
8		65	28	76	22½	8½	60
Siberian, No. 22424:[b]							
1		120	25	26	22½	7	45
5		95	8	9	23	6¾	41
9		140	16	13	21½	5	30
10		95	13	16	23	5½	31
Hungarian, No. 22426:[b]							
1		170	15	10	30½	3	11
3		170	13	8	28	4½	19
7		127	19	17	26½	5¾	28
8		120	12	11	25	4½	22
S. P. I., No. 20694:							
1		55	5	10	26	5½	27
2		90	7	8	....	....	....

AVERAGE YIELDS OF ALL THE SELECTIONS AND PROGENIES.[c]

Variety and selection.	Number of selections in 1908 and of progeny rows in 1909.	Total dry weight of plant.	Weight of seed.	Proportion of seed to 100 parts of straw.	Total dry weight of plants.	Weight of seed.	Proportion of seed to 100 parts of straw.
Kursk, No. 22420	15	108	23	27	27	8⅗	47
Common, No. 22423	8	86	31	56	18	7⅗	63
Siberian, No. 22424	10	122	16	15	21	5⅗	36
Hungarian, No. 22426	8	130	13	11	25	4⅘	24

[a] The yields of the different progenies are strictly comparable because the rows were of uniform length and the stands were all perfect.

[b] Only those selections from each variety are here included of which the progenies in 1909 gave yields of seed and of total dry matter above the average for the progenies of all the selections made in 1908 of that particular variety.

[c] Including selections the progenies of which yielded low in 1909 and were hence excluded from the preceding showing.

Some interesting results are shown in the millet-breeding work as recorded in the above table. It will be noted in the record of averages that the Kursk is the highest yielding variety in the progeny rows grown in 1909, both in total weight of plant and weight of seed. Kursk is considerably ahead of any other variety in yield of seed though the Common variety exceeds it in proportion of seed to straw.

It will also be noted that the yields of seed and straw of the progenies, in general, correspond rather closely with those of the respective mother plants. This is especially marked in the Kursk and Common varieties. For example, in the Kursk variety, seven selections are separately listed in which the progeny of each yielded above the average of all rows. As shown in Table VI, the selected mother plants all yielded above the average in total weight of plant, except No. 1 and No. 4. Selections 6, 7, 9, 12, 14, and 15 (not separately shown in the table) yielded below the average of both mother plants and progeny.

DATES OF RIPENING.

The average dates of ripening and the average number of days from date of planting to maturity for the selected varieties for the two years were about as follows:

TABLE VII.—*Date of ripening and length of growing period of several selected varieties of millet at Bellefourche, S. Dak.*

Variety.	Date of ripening.	Maturing period. (days)
Common	August 24	96
Kursk	August 28	100
Hungarian	September 7	110
Siberian and No. 20694	September 10	113

It will be seen that the Common and Kursk varieties are earlier by ten days or more than the Hungarian and Siberian. Earliness in ripening is an important factor in all dry-land crops, especially millet, which is often used as a catch crop to replace a previously destroyed crop.

UNIFORMITY IN THE PROGENY ROWS.

It was noted in the breeding plats that the progeny rows from the different selections of Kursk resembled one another much more closely than the progeny rows from any other variety. This may be accounted for by the fact that the bulk seed from which these Kursk selections were made was itself the product of two selections made at Highmore only three or four generations back. There seems also to be great uniformity among the plants in each progeny row.

The selected plants have been remarkably true to seed from the beginning, indicating that millet is probably a self-pollinated plant. This belief is based on the general uniformity of the plants in the progeny rows as observed by the writer in all his breeding work with this crop.

MILLET BREEDING AT THE AKRON DRY-LAND STATION.

Seed of several selections of millet made at the Bellefourche Experiment Farm in 1908 was used for beginning the breeding work at the Akron Dry-Land Station in 1909. These selections were the same as those planted at Bellefourche, sufficient seed being borne by each plant for use at both stations.

TABLE VIII.—*Yield of millet selections of 1908 and of their progenies grown at Akron, Colo., in 1909.*

Variety and selection.	Individual plant selections made at Bellefourche in 1908.			Progeny grown at Akron in 1909.				
				Yields from actual stands.				
	Total dry weight of plant.	Weight of seed.	Proportion of seed to 100 parts of straw.	Total dry weight of plants.	Weight of seed.	Proportion of seed to 100 parts of straw.	Stand in row.	Total dry weight calculated to a full stand.[a]
Kursk, No. 22420:	*Grams.*	*Grams.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*
1	100	29	40	18¾	7¼	63	80	23.2
2	125	43	52	39	18	86	95	41.0
3	150	25	20	33½	14¾	79	100	33.5
5	130	27	26	42	17	68	100	42.0
10	130	29	29	33¾	14¼	73	100	33.7
13	145	30	26	39½	17½	80	100	39.5
15	100	29	42	28½	12	73	90	31.6
Average	126	30	34	33	14½	75	....	34.9
Common, No. 22423:								
1	112	42	60	22½	10½	87	80	28.0
2	82	40	95	13¾	4¼	45	75	18.3
3	75	33	79	19½	6¼	47	70	28.0
4	95	33	53	27¼	13½	98	95	29.0
7	100	38	61	19¼	9	88	95	20.3
8	65	28	76	24¼	12	98	95	25.6
Average	88	36	71	21	9	77	....	24.8
Siberian, No. 22424:								
1	120	25	26	15½	6¼	68	80	19.4
4	175	25	17	37	15½	72	90	41.0
Average	147½	25	21½	26	10.9	70	....	30.2

[a] This calculation is doubtless too favorable to the rows in which the stand was incomplete, since the plants growing near the gaps unquestionably yielded more heavily than would the average plant in a row in which the stand is complete.

The yields of millets in the progeny rows in 1909 were considerably heavier at Akron than at Bellefourche. This fact is not only apparent by comparison of the average yields of all the progenies of each variety at Bellefourche (Table VI) and at Akron (Table VIII), but generally holds good in the case of progenies of those individual selections of which the seed was divided and planted partly at Bellefourche and partly at Akron. The heavier yields at Akron were doubtless largely due to the more favorable season at that locality in 1909. The rainfall there was well distributed throughout the growing season, while at Bellefourche there was less than 3 inches of rain during July and August, which is the critical period in the growth of millet. It was noted that the yield of seed in many of the rows at Akron was remarkably high. The average seed yield of the Kursk progeny rows was 14½ pounds per row, which is equivalent to a yield of 25 bushels per acre. The largest yield, from Kursk selection No. 2, of 18 pounds to the row, is at the rate of 32 bushels per acre.

As shown by the averages for the progenies of each variety, the Kursk is first in total weight of plant and weight of seed. The superior yield of Kursk millet when grown in cultivated rows is a marked character of the variety. This is no doubt partly due to its strong stooling habit and vigorous growth. It has been noted by the writer that in seeding millets broadcast a much heavier stand is secured in the Kursk variety than in others when the same amount of seed is used per unit area. This makes it desirable to seed somewhat less of this per acre than of other varieties, especially under dry-land conditions.

In 1910 the seed of the best progeny rows grown in 1909 were planted in $\frac{1}{10}$-acre plats in comparison with standard varieties. These tests will be continued until the forage value of the different selections as compared with one another and with other varieties under conditions of severe drought can be ascertained.

BROME-GRASS.

Smooth or Hungarian brome-grass (*Bromus inermis*) is one of the most drought-resistant grasses grown in the northern Great Plains. It is well adapted to cultivation on account of its abundant seed production and vigorous habit of growth, and it has come into general favor in the Central Northwest since its introduction into the United States.[a] Several stocks of seed were tested at the Highmore substation previous to and during the time cooperation was carried on between the Bureau of Plant Industry and the South Dakota Agricultural Experiment Station. One of these stocks, listed as South Dakota No. 26, appeared to be decidedly superior to the others in forage production. This strain is rather distinct in type of plant and has light-colored outer glumes or scales around the seeds which give the mature panicle an exceptionally light-colored appearance. The plants are strong and vigorous and remain productive for several years; that is, the strain does not "run out" quickly. Bulk seed of this strain was planted broadcast and in double-cultivated rows at the Bellefourche Experiment Farm in 1909. A breeding nursery occupying two $\frac{1}{10}$-acre plats was also planted. The seed was planted in hills 42 inches apart each way and the hills were thinned to individual plants in early summer. An excellent stand was secured in all the plats. There is great diversity in the manner of growth of the individual plants in the breeding nursery. Many of them are erect and close growing, while others are inclined to spread greatly by rootstocks. There is also great diversity as to amount of leafiness and amount of stooling. Altogether there is great opportunity for selection of superior types. In addition to the work in the breeding nursery tests are being made of several individual selections of *Bromus inermis* furnished by the Office of Forage-Crop Investigations. These are planted in progeny rows.

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[a] For a chemical analysis of brome-grass, see Table IX.

WESTERN WHEAT-GRASS.

Western wheat-grass, botanically known as *Agropyron smithii* (*A. occidentale*), is native over a large part of the northern Great Plains and is valued highly as a pasture and hay grass. It is especially common on the "gumbo" soils in western South Dakota. Along the river and creek bottoms, where subject to annual overflow, it forms a dense, vigorous growth and is the most valuable native hay grass of the region. In such places it forms a pure growth unmixed with other grasses. On the dry ranges it forms a considerable part of the native forage and is remarkably drought resistant. The growth on the ranges, however, is scattered and thin. In depressed areas where drainage is poor or which receive the drainage from higher areas the wheat-grass occurs to the exclusion of other native grasses. This is doubtless due partly to its great alkali resistance and partly to its ability to endure rather long periods of flooding. The alkali content of the soil in these areas ranges as high as 0.4 to 0.6 of 1 per cent.

Wheat-grass hay is locally in great demand in South Dakota. It is especially valuable for feeding to livery and other horses doing hard work. For this purpose it sells for $4 to $5 more per ton than alfalfa and mixed hay at Bellefourche, Deadwood, and other places in the Black Hills.

Chemical analyses indicate that it is especially rich in crude protein and ether extracts. The following analyses of some common native and cultivated forage plants of South Dakota are here given for purposes of comparison:

TABLE IX.—*Chemical analyses of some common native and cultivated forage plants of South Dakota.*

Name of forage plant.	Name of analyst.	Ash.	Ether extract.	Crude fiber.	Crude protein.	Nitrogen-free extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Western wheat-grass (*Agropyron occidentale*).	Shepard[a]	8.52	2.91	34.90	9.80	43.88
	Knight and Kepner.[b]	5.03	3.07	36.70	9.23	45.97
Slender wheat-grass (*Agropyron tenerum*).	Shepard[a]	5.74	2.77	32.44	8.90	50.15
Smooth brome-grass (*Bromus inermis*).	....do.[a]	8.08	2.06	41.27	10.79	37.80
	Knight and Kepner.[b]	6.21	2.71	29.50	9.47	52.11
Buffalo-grass (*Bulbilis dactyloides*).	Shepard[a]	11.19	2.46	28.74	5.60	52.02
	Knight and Kepner.[b]	11.60	2.42	26.81	8.34	50.83
Blue grama (*Bouteloua oligostachya*)	Shepard[a]	8.69	2.18	31.40	9.11	48.62
Timothy (*Phleum pratense*)	....do.[a]	7.39	3.58	34.39	8.84	45.80

[a] Shepard, J. H. Bulletin 40, South Dakota Agricultural Experiment Station, 1894.
[b] Knight, H. G., and Kepner, F. E. Bulletin 76, Wyoming Agricultural Experiment Station, 1908.

It will be noted that in the percentage of fats (ether extracts) western wheat-grass is very high, being excelled only by timothy. It is also high in amount of crude protein, but is excelled in this by

Bromus inermis. It is therefore very rich in two of the most important food constituents, and this accounts for its great feeding value as demonstrated by the practical feeder. One other character which may be mentioned is the comparatively concentrated form of the cured hay; that is, the weight per unit volume is great as compared with most hay grasses.

Breeding work was begun with western wheat-grass at the Highmore substation by Prof. W. A. Wheeler in 1905. These breeding plats were visited several times by the writer, the last visit having been made in August, 1908. At this time there appeared to be considerable uniformity in many of the progeny rows from the first selections. South Dakota No. 34–89 was uniformly more spreading than the rows at each side of it: No. 34–105 was also noticeably spreading in habit of growth, while No. 34–81 was close growing, showing a slight approach to bunch-grass habit.

Breeding work was begun at the Bellefourche Experiment Farm in 1908 with bulk seed harvested from natural meadows near the farm. It is desired to secure a drought-resistant and productive strain, suitable for establishing permanent grass meadows on unirrigated land. It is very important to improve the seed production and percentage germination of the seed and the early growth habits of the plant. The germination of the seed is poor and slow and the early growth is not vigorous. It is therefore difficult to obtain a good stand of the grass. Both spring and autumn seeding are being tested to determine which method will produce the better stand. The results so far are not conclusive.

A breeding nursery has been established with single plants in hills 42 inches apart each way. These were grown from seed planted in the field in 1909.

SLENDER WHEAT-GRASS.

Slender wheat-grass, botanically known as *Agropyron tenerum*, appeared to be valuable as a cultivated hay grass in variety tests by the South Dakota substation at Highmore, and by the Office of Forage-Crop Investigations at Bellefourche. The seed germinates freely and the first season's growth is good, so that there is not the difficulty in securing a stand that is experienced with western wheat-grass; but this species is apparently not so drought resistant as brome-grass and western wheat-grass.

Seed collected from plants growing native in western South Dakota was planted in the grass nursery at Bellefourche in 1908 (Pl. IV, fig. 2). In 1909 individual plants were selected from this nursery and these will form the basis of the breeding work with this grass.

Considerable variation among the individual plants was noted in height, amount of stooling, and leafiness. The most desirable types were those which have the leaves extending well up along the culms, thus producing a very leafy plant. There was much variation in this regard. In 1910 the seed of these selections was planted in rows so that a close comparison could be made of their progeny. A few individual plant selections of slender wheat-grass were furnished by the Office of Forage-Crop Investigations, and these were planted in progeny rows in 1909.

AGROPYRON CRISTATUM.

The grass botanically known as *Agropyron cristatum,* recently introduced from Siberia by the United States Department of Agriculture, gives evidence of being a very hardy grass. In cooperation with the Office of Forage-Crop Investigations, seed of six different lots, S. P. I. Nos. 19536 to 19541, inclusive, was planted in the grass nursery at Bellefourche in 1908 (Pl. IV, fig. 1), and larger areas were planted again in 1909. It was observed that this species starts growth very early in the spring, and is not injured by severe frosts. In habit of growth it is like slender wheat-grass, being a "bunch-grass" without creeping rootstocks, but in the character of its rather harsh foliage it somewhat resembles western wheat-grass. Further tests will be made of seed from several sources, and if the species proves to be valuable as a hay grass, selections of superior strains will be made.

CANADA PEAS.

The Office of Forage-Crop Investigations tested a large number of varieties of Canada peas, grass peas (*Lathyrus sativus*), and several varieties of vetches at the Bellefourche Experiment Farm in 1908 and 1909. The yields of most of these have not been satisfactory in the two years during which tests have been made. The low yields have probably been due to the newness of the soil at the farm, as the plats were on land broken only one year previous to cropping. Two or three varieties of Canada peas, however, are very promising, and breeding work has been begun with these.

In dry-land farming the need of an annual leguminous crop for use as green manure in short rotations is apparent, and Canada peas promise to be the most valuable crop for this purpose in the northern Great Plains region. The breeding work will be directed to obtaining a more drought-resistant variety than is now grown in the region, combining also fair seed production with a good forage type of plant.

SUMMARY.

The chief limiting factor in the production of crops in the Great Plains area is lack of sufficient moisture. Two ways of increasing crop production in that region are: First, the use of tillage methods which will conserve the moisture in the soil as far as possible for the use of crops; and second, growing drought-resistant varieties.

The object of the plant-breeding work described in this bulletin is to develop strains of some of the common forage crops that are more drought resistant and productive than strains now grown in the region.

Drought-resistant forage-breeding work is now carried on at two farms conducted by the Department of Agriculture in the Great Plains area, at Bellefourche, S. Dak., and at Akron, Colo. These farms are fairly representative of a large part of the northern and central Great Plains.

In breeding alfalfa for this region, while drought resistance is the principal object in view, such characters as resistance to winter-killing, superior forage yield, and good seed production can not be neglected.

The results of the breeding work with alfalfa indicate that superior forage production and superior seed production are not antagonistic, but may be combined in one plant or strain.

Maximum seed production in alfalfa can be obtained by growing plants in hills, allowing thorough cultivation of the soil. This method can be recommended only where seed is the chief object of the crop.

Breeding sorgo at Bellefourche has been undertaken for the purpose of developing a drought-resistant and early-maturing strain of good forage quality. The existence of such a strain would extend the use of the crop considerably north of its present area.

Most millet varieties now on the market are mixtures of more or less distinct types. In the breeding work conducted by this office, several promising types have been segregated and have shown a high degree of uniformity. They will be tested further for drought resistance, early maturity, and forage yield.

Numerous species of grasses have been tested for drought resistance in the course of the breeding work at Highmore, and by the Office of Forage-Crop Investigations at Bellefourche and other stations in the Great Plains area. Breeding work is in progress with species that have proved drought resistant and otherwise valuable, including smooth brome-grass, western wheat-grass, and slender wheat-grass.

CONCLUSION.

It is intended to test thoroughly the improved strains which have been developed in the course of this work in order to determine their relative drought resistance in comparison with varieties now grown in the region. The most promising strains of alfalfa will also be thoroughly tested in respect to their hardiness. As soon as definite results from these tests of drought resistance and hardiness are obtained, seed of such strains as may prove resistant will be increased and distributed.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Alfalfa breeding at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Alfalfa plants in the breeding nursery, showing the first season's growth. The photograph was taken July 29, 1909, three months after planting. The rows are from individual plant selections of the second generation, South Dakota No. 167. Fig. 2.—Selected strains of alfalfa in double-cultivated rows (rows 7 inches apart alternating with cultivated space 32 inches wide).

Plate II. Sorgo at the Highmore substation and the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Sorgo, South Dakota No. 341, at the Highmore substation, South Dakota. The selected strain at the left is ten days earlier than the bulk seed of the same variety at the right. Fig. 2.—Sorgo progeny row No. 10, showing uniform type of plants. Grown at the Bellefourche Experiment Farm, South Dakota, in 1909, from seed of a single plant selected in 1908.

Plate III. Kursk millet at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Selection rows of Kursk millet at the Bellefourche Experiment Farm, South Dakota. The individual plants are grown in hills 8 inches apart. Fig. 2.—Progeny rows of Kursk millet grown at the Bellefourche Experiment Farm, South Dakota, in 1909. These are the progenies of plants selected in the rows shown in figure 1.

Plate IV. Agropyron in the grass nursery at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Rows of *Agropyron cristatum* in the grass nursery at the Bellefourche Experiment Farm, South Dakota. In 1909 this grass was ten days earlier in starting spring growth than any other species in the nursery. Fig. 2.—Rows of *Agropyron tenerum* in the grass nursery at the Bellefourche Experiment Farm, South Dakota. This is a valuable type of hay grass and breeding work is being carried on in the hope of segregating a more drought-resistant strain.

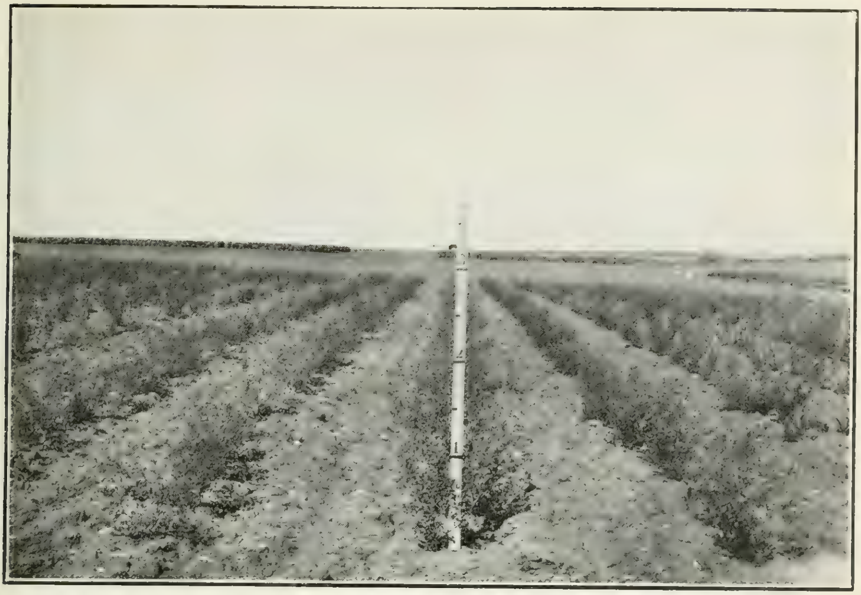

FIG. 1.—ALFALFA PLANTS IN THE BREEDING NURSERY, SHOWING THE FIRST SEASON'S GROWTH.

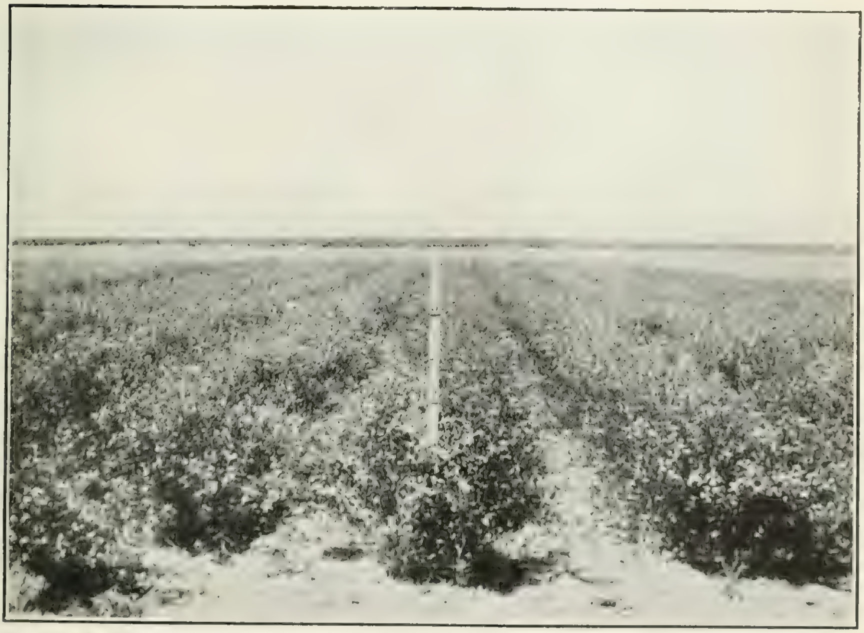

FIG. 2.—SELECTED STRAINS OF ALFALFA IN DOUBLE-CULTIVATED ROWS.

ALFALFA BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

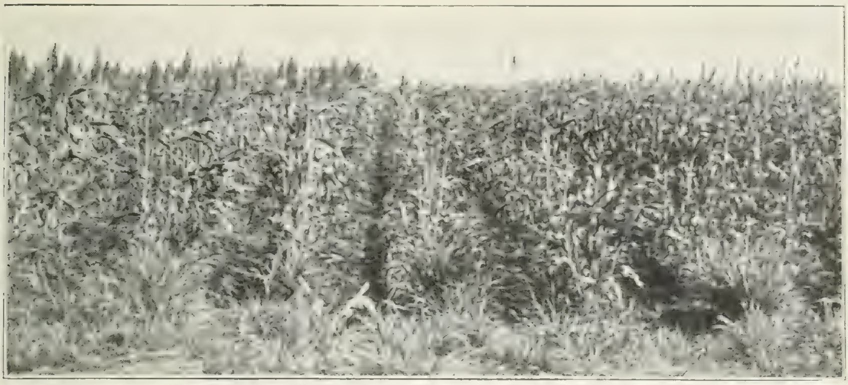

FIG. 1.—SORGO, SOUTH DAKOTA NO. 341, AT THE HIGHMORE SUBSTATION, SOUTH DAKOTA.

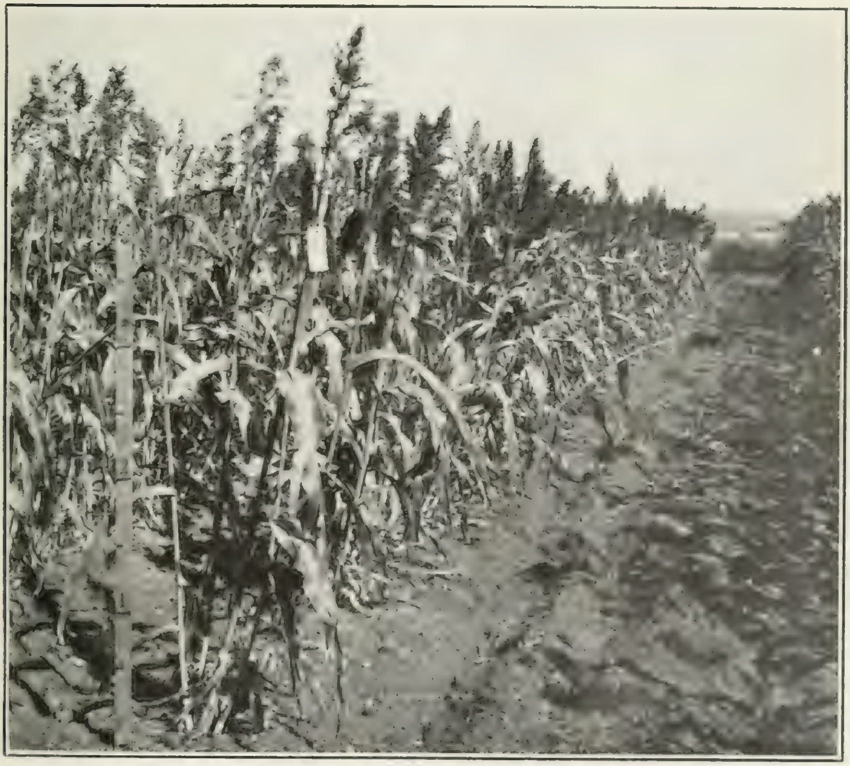

FIG. 2.—SORGO PROGENY ROW AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA, SHOWING UNIFORMITY OF PLANTS.

SORGO AT THE HIGHMORE SUBSTATION AND THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

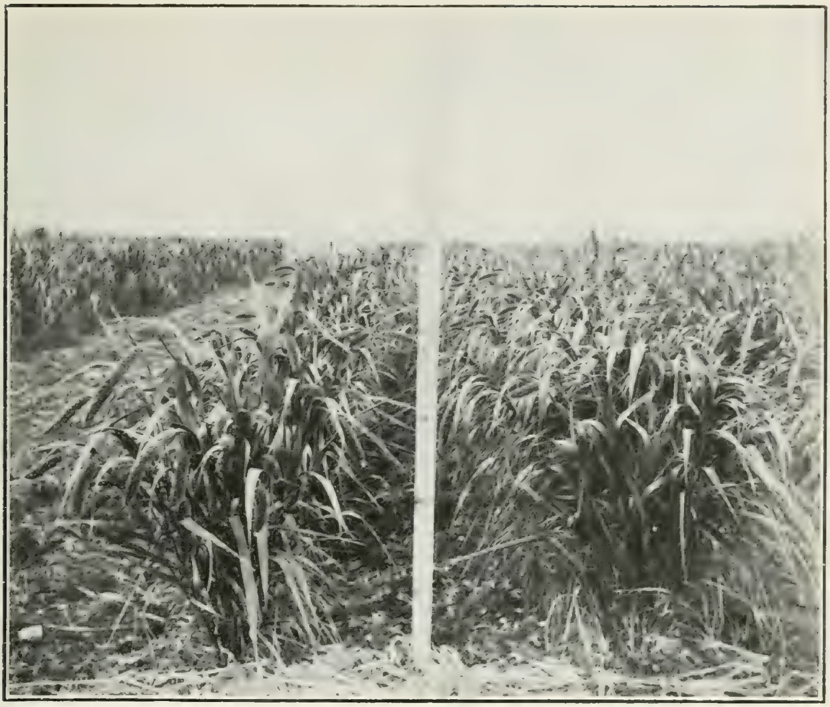

FIG. 1.—SELECTION ROWS.

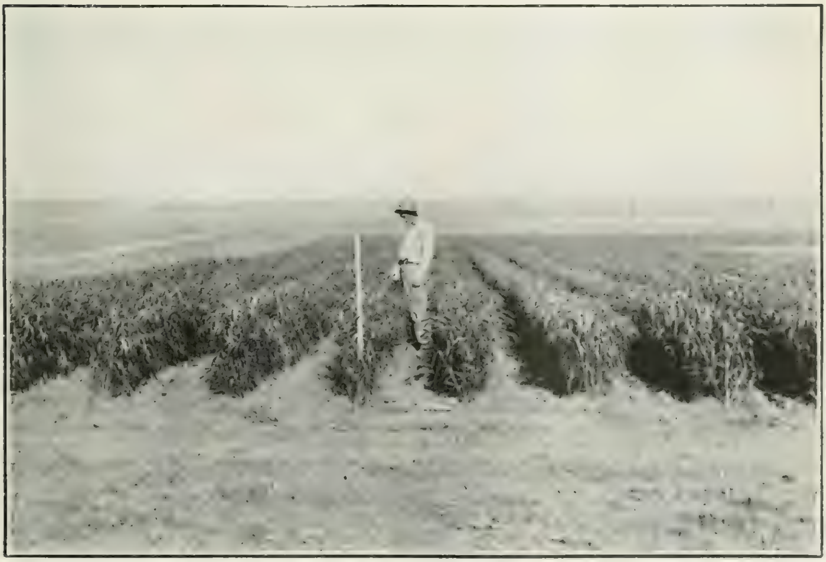

FIG. 2.—PROGENY ROWS.

KURSK MILLET AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

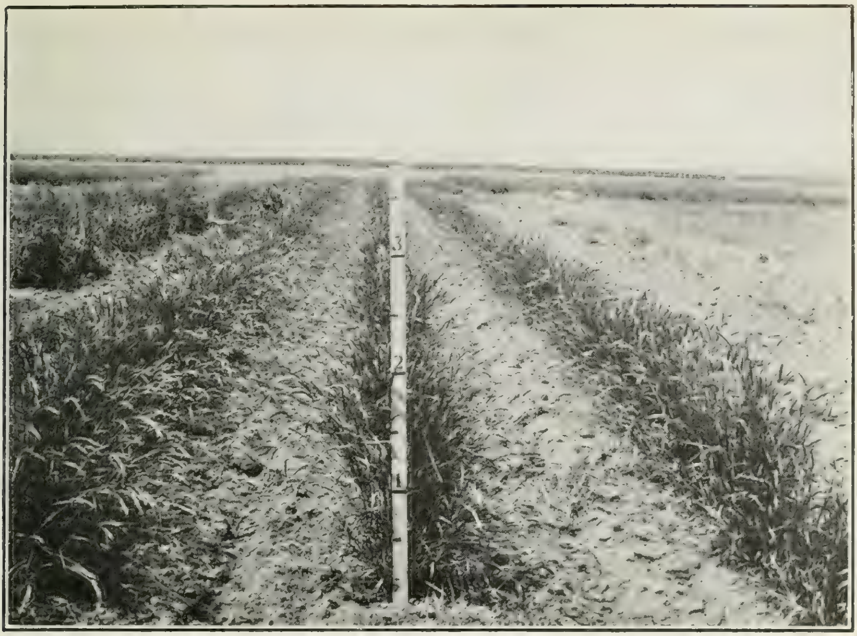

FIG. 1.—ROWS OF AGROPYRON CRISTATUM.

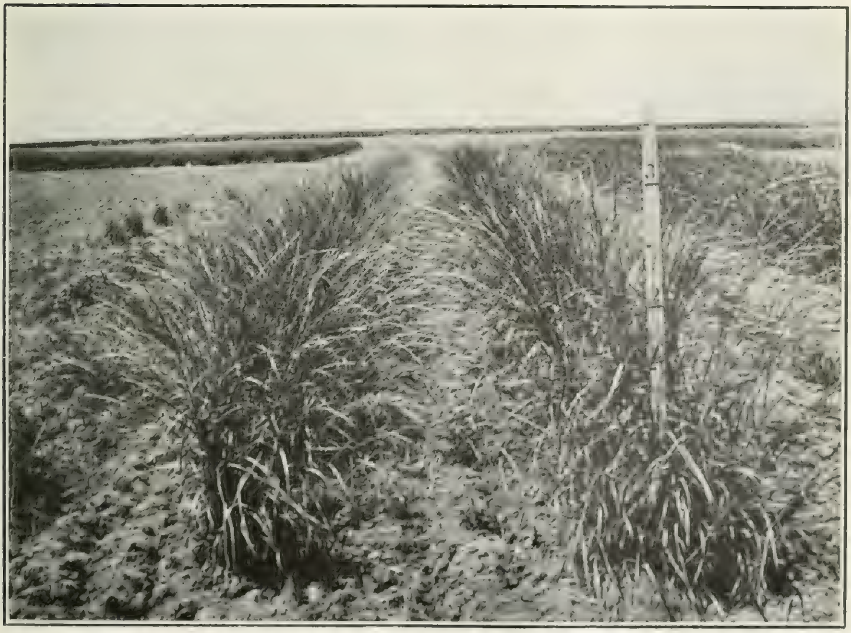

FIG. 2.—ROWS OF AGROPYRON TENERUM.

AGROPYRON IN THE GRASS NURSERY AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

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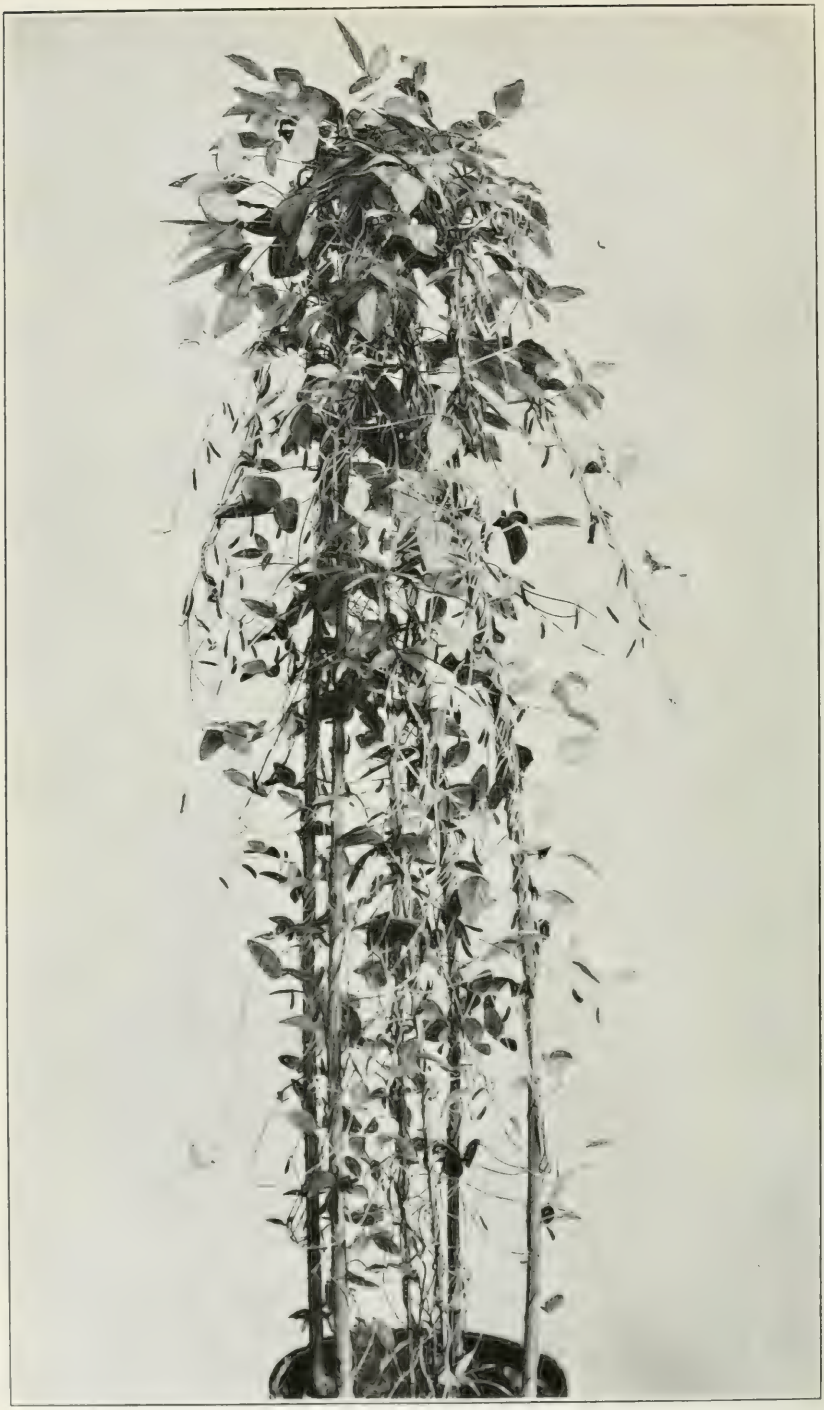

PLANT OF A WILD SOY BEAN, NO. 22428, GROWN IN A GREENHOUSE.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 197.
B. T. GALLOWAY, *Chief of Bureau.*

THE SOY BEAN; HISTORY, VARIETIES, AND FIELD STUDIES.

BY

C. V. PIPER, AGROSTOLOGIST,

AND

W. J. MORSE, SCIENTIFIC ASSISTANT,
FORAGE-CROP INVESTIGATIONS.

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FORAGE-CROP INVESTIGATIONS.

SCIENTIFIC STAFF.

C. V. Piper, *Agrostologist in Charge*.

J. M. Westgate, *Agronomist*.
R. A. Oakley and H. N. Vinall, *Assistant Agrostologists*.
S. M. Tracy, *Special Agent*.
A. B. Conner, A. B. Cron, M. W. Evans, Roland McKee, and W. J. Morse, *Assistants*.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 3, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 197 of the series of this Bureau the accompanying manuscript entitled "The Soy Bean: History, Varieties, and Field Studies."

This paper was prepared by Mr. C. V. Piper, Agrostologist, and Mr. W. J. Morse, Scientific Assistant, of the Office of Forage-Crop Investigations.

The soy bean is a striking example of a crop with very numerous varieties, the wealth of which has been largely disclosed by the studies here presented. This crop is already of considerable value in the United States, and there can be but little doubt that it is destined to become of much greater importance, not only for forage, but in all probability for the production of oil and oil cake. The results here presented bring together much information that will be of interest to students and experimenters, and which, it is believed, will be of material assistance to all agronomic investigators.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE SOY BEAN; HISTORY, VARIETIES, AND FIELD STUDIES.

BOTANICAL HISTORY AND IDENTITY OF THE SOY BEAN.

The soy bean was first made known to Europeans by Kämpfer, who spent three years, 1690 to 1692, in Japan. Kämpfer (Amœnitatum Exoticarum, 1712, p. 837) gives the Japanese name "Daidsu Mame" and describes it as an erect bean, with the pod of a lupine and the seeds like a large white pea. Linnæus (Flora Zeylanica, 1747, p. 534) describes the plant briefly under "Dolichos" and states that it is cultivated in Ceylon. This last statement is probably an error. He also cites the descriptions of Kämpfer. In 1753 Linnæus repeats the description of the Flora Zeylanica and formally names the plant *Dolichos soja*, giving its habitat, however, as India. What Linnæus's Ceylon or India plant may be is not certain, as will appear.

Moench in 1794 rechristened the Linnæan plant *Soja hispida*. Savi in 1824 called the Japanese soy bean *Soja japonica*. Miquel in 1855 named a narrow-leafed form from Java *Soja angustifolia*, and Maximowicz in 1873, using Moench's specific name, published the soy bean as *Glycine hispida*, which name has been generally adopted. Siebold and Zuccarini had previously (1843) named a plant from Japan *Glycine soja*, supposing it to be the *Dolichos soja* of Linnæus. This plant, however, was not the soy bean cultivated by the Japanese but the wild plant later described as *Glycine ussuriensis* by Regel and Maack. Under existing botanical rules, the soy bean, which is known only as cultivated, has been called *Glycine hispida* (Moench) Maximowicz, and its nearest relative *Glycine soja* Siebold and Zuccarini (*G. ussuriensis* Regel and Maack). Maximowicz considered that the soy bean was probably derived from the latter by cultivation, but this idea has not generally been accepted.

Glycine soja (Pls. I and II), as heretofore known, differs from *G. hispida* in its more slender and more vining stems, in being less hairy, in bearing smaller pods and seeds, and especially in having smaller flowers. The flower is 3 to 5 mm. long, while that of *G. hispida* is 6 to 7 mm. The structure of the flower is the same in both, but the calyx lobes are usually longer in proportion to the tube in *G. hispida* than in *G. soja*. It is apparent, therefore, that the fundamental differences between the species are slight. The smaller flower we regard as the best single character to separate *G. soja* from *G. hispida*, but using this as a criterion *G. soja* is also a cultivated species.

Among numerous lots of seeds received from India (S. P. I. Nos. 24672 to 24693, inclusive) representing seven varieties, there are at least two (see Nos. 24675 and 24682) which have very small flowers, 3 mm. long, indistinguishable from those of the wild *G. soja* that we have grown. Typical plants of *Glycine soja* obtained from the Botanic Garden, Tokyo, Japan (S. P. I. No. 22428), and from Soochow, Kiangsu, China (S. P. I. No. 25138), have been grown three seasons. The India plants are coarser stemmed, less vining, and bear somewhat larger pods and seeds, but the flowers are much smaller than those of any variety of *G. hispida* and precisely like those of *G. soja*. Other numbers from India are probably *G. hispida*, but the flowers are somewhat smaller than the Japanese varieties and the pods and seeds as small as any variety of *G. hispida*. It is therefore apparent that both *G. soja* and *G. hispida* are cultivated in parts of India, if we accept the flower character as decisive. This fact makes it doubtful which of the two plants Linnæus named *Dolichos soja*. There seems no good reason why *G. hispida* may not have been derived from *G. soja* by cultivation, the smaller flowers of the latter being the principal difficulty to explain. In all other respects the two supposed species seem to merge completely. The identity of the plant cultivated in India has been commented on by Watt (Dictionary of the Economic Products of India, 1890, p. 509) as follows:

> Reference having been made to the authorities of the Calcutta Herbarium on the subject of *G. soja*, Sieb. et Zucc., being, as shown in the Flora of British India, a native of this country, Dr. Prain kindly went into the subject very carefully. He writes: "We have not, from any part of India, any specimens of *G. soja* proper. The Khasi Hills plant is more erect, more hispid, and has larger legumes than the Himalayan, and indeed resembles *G. hispida*, Maxim., quite as much as it does the Indian cultivated '*G. soja*,' which, indeed, it connects with *G. hispida*. It is, in fact, the plant most like the wild *G. soja*, S. et Z., which no one ever professes to have found wild in India, while it is also the one most like *G. hispida*, Maxim. (which has never been found wild anywhere). It is the plant collected by Dr. Watt and myself in the Naga Hills."
>
> The writer noted on his Naga Hill specimens that they were found in a semiwild state, and that the plant was known to the Angami Nagas as *Tsu Dza*, a name not unlike *soja*. Throughout India, the soy bean is cultivated, black and white seeded forms being met with, which vary to some extent, but all preserve the specific characters of *G. hispida*. Plants raised at Saharunpur from Japanese seed have larger and broader leaves than the usual Indian forms. The fact that this cultivated plant possesses, even among the aboriginal tribes, names which are original, i. e., in no way modern derivatives, points to an ancient cultivation, if, indeed, it may not be accepted as an indication of its indigenous nature. (Editor.)

Prain apparently does not apply the size of the flower as a critical character. Applying this, however, two of the Indian varieties (see

Nos. 24675 and 24682) are certainly *Glycine soja*, but the plants are stouter and less twining, and the pods and seeds larger than the wild form from Japan. Three other varieties (Nos. 24672, Khasi Hills, and 24673 and 24674, Darjiling) we would refer to *G. hispida*, though the flowers are somewhat smaller than the Japanese and Chinese varieties. The first is erect and bushy, but the other two are procumbent and vining. A variety from Taihoku, Formosa, No. 24642, is very similar to the two varieties from Darjiling. On the whole, we are therefore inclined to believe that there is but one botanical species, which has been profoundly modified by cultivation.

BOTANICAL CLASSIFICATIONS OF SOY-BEAN VARIETIES.

The numerous varieties of soy beans have led some botanists to give them botanical designations, but these for the most part have been ignored by later writers.

Roxburgh (catalogue, p. 55) described a variety in the Calcutta Botanical Garden as *Soja hispida pallida*, stating that it had yellow flowers and white seeds. Voigt (Hortus Suburbanus Calcuttensis, p. 231) apparently redescribes the same plant as *Soja hispida leucosperma*. There is perhaps an error here as all of the varieties of soy beans grown by us have either white or purple flowers and none have truly white seeds.

Martens (Die Gartenbohnen, 1869) discusses the soy bean under the name *Soja hispida* Moench and gives a classification of thirteen varieties that he had secured from various sources, of which he apparently grew but one. He divides the species into three subspecies based on the form of the seed, under which the varieties are named according to the color of the seed.

I. *Soja elliptica* Martens. Seeds oval.
  1. *S. elliptica nigra*. Seeds black; obtained from Shanghai and Paris.
  2. *S. elliptica castanea*. Seeds brown; obtained from Chefoo, Venice, and Berlin.
  3. *S. elliptica virescens*. Seeds greenish yellow; obtained from Paris.
  4. *S. elliptica lutescens*. Seeds yellow; obtained from Chefoo.

II. *Soja sphaerica*. Seeds globose.
  5. *S. sphaerica nigra*. Seeds black, large; obtained from Japan.
  6. *S. sphaerica minor*. Seeds black, small; obtained from Japan and Sumatra.
  7. *S. sphaerica virescens*. Seeds greenish; obtained from Shanghai and Yokohama.
  8. *S. sphaerica lutescens*. Seeds yellow, large; obtained as "New Japan peas" from Norway. This is identified as var. *pallida* of Roxburgh.
  9. *S. sphaerica minima*. Seeds yellow, small; obtained from Yokohama.

III. *Soja compressa*. Seeds compressed.
  10. *S. compressa nigra*. Seeds black, very large; obtained from Yokohama.
  11. *S. compressa parvula*. Seeds black, small; obtained from Chefoo.
  12. *S. compressa virescens*. Seeds greenish; obtained from Berlin as *Soja ochroleuca* Bouché.
  13. *S. compressa zebrina*. Seeds brown banded with black; obtained from the Berlin Botanic Garden.

Harz (Zeitschrift des Landw. Vereins Bayern, 1880, and Landwirtschafthliche Samenkunde Handbuch, 1885) gives an even more elaborate classification than Martens of the varieties of *Soja hispida*, dividing the species into two subspecies on the form of the pod, and numerous varieties on the shape and color of the seeds, but it is not apparent that he grew the plants. His grouping is as follows:

Soja platycarpa Harz. Flat-podded soy beans.

1. *olivacea* Harz. Seeds olive-brown.
2. *punctata* Harz. Seeds olive, speckled with brown.
3. *melanosperma* Harz. Seeds black, elongate (*Soja compressa nigra* Martens).
   - a. *vulgaris.* Hilum flat; seeds 9.1×5.5×3.5 mm.
   - b. *renisperma.* Hilum concave; seeds 10.1×5×3.8–4 mm.
   - c. *nigra.* (*Soja elliptica nigra* Martens.) Seeds little compressed, 11×5.1×4.4 mm.
   - d. *rubrocincta.* Like the preceding, but dark red about the hilum.
4. *platysperma* Harz. Seeds black, flat.
5. *parvula* Martens. Seeds black, small.

Soja tumida Harz. Swollen-podded soy beans.

6. *pallida* Roxb. Seeds yellow or yellowish.
7. *castanea* (*Soja elliptica castanea* Martens). Seeds brown.
8. *atrosperma* Harz. (*Soja sphaerica nigra* and *S. sphaerica minor* Martens.) Seeds black.

This classification differs from that of Martens primarily in recognizing two main groups based on the shape of the pod rather than three groups based on the form of the seed.

While either the system of Martens or that of Harz will classify the material, they are of little value either botanically or agronomically. To accommodate the much larger number of varieties we have studied, either scheme would need to be elaborated greatly. Furthermore, there are all possible intergrades between flat pods and tumid pods, as also between oval, globose, and compressed seeds. Botanically speaking, the form of the pod and the color and form of the seeds is of little significance. Agronomically the habit and size of the plants are much more important characters, and in many cases varieties very different in these respects have closely similar seeds.

VARIETAL CHARACTERISTICS OF SOY BEANS.

The characters that distinguish soy-bean varieties may be considered under the following categories:

HABIT OF GROWTH.

All soy beans are strictly determinate as to growth; that is, the plants reach a definite size according to environment and then mature and die. The great majority of the varieties are erect and branching, with a well-defined main stem. (Pls. II and III.) The branches may all be short, or the lower ones elongated, either spreading or ascending.

In other varieties the stems and branches, especially the elongated terminals, are more or less twining and usually weak, so that the plant is only suberect or even procumbent. (Pls. I, II, and III.) In the bushy forms the internodes may be short, in which case the pods are more or less densely crowded or elongated, causing the pods to be scattered. Varieties with elongated internodes are usually slender and the pods small, but this is by no means universal. The form of the plant may be greatly modified by thickness of planting, as the development of the branches is inhibited by close planting and encouraged by isolation.

FOLIAGE.

There is wide variation in the leaves of soy beans, involving shape, size, color, and degree of persistence. These characters merge by insensible degrees, so that they are useful in differentiating varieties only in extreme cases. In shape, the leaflets are usually ovate-lanceolate, but in some varieties are narrowly lanceolate or almost linear; in others, nearly orbicular. They vary in length from 1 inch to 5 inches. In color they are usually pale, but some are dark green.

In nearly all varieties of soy beans the leaves commence to turn yellow as the pods begin to ripen and commonly all have fallen when the pods are mature. On this account it is difficult to harvest the crop for grain and save all the foilage as well, but this is possible with many varieties. A few sorts, like the Wisconsin Black, retain their leaves green until all or nearly all of the pods are mature.

Additional leaflets occur not uncommonly in several varieties. This seems to be especially true with early sorts from Siberia, on which leaves with four or five leaflets are frequently seen.

PUBESCENCE.

All soy beans are hairy plants, and there is but little difference in the amount of hairiness. No smooth variety has thus far been obtained, the nearest approach to it being No. 22876, from Tokyo, Japan. The pubescence occurs in two colors, white or gray and tawny, which behave in Mendelian fashion, the tawny being dominant. The tawny pubescence is nearly always on tawny-colored or dark pods and the white pubescence on grayish pods. Many cases occur where two varieties differ wholly or mainly in the color of the pubescence. In some instances these have been segregated; in others the mixture is evident. In such cases one color usually predominates, the presence of the other being due to casual hybridization.

FLOWERS.

Soy-bean flowers occur in two colors, purple and white. Certain varieties can be distinguished most readily by this character. In a number of the lots tested both colors of flowers occur, the plants otherwise resembling each other very closely. Two strains of this sort can, however, be readily separated. Roxburgh (Catalogue, p. 55) and Voigt (Hortus Suburbanus Calcuttensis, p. 231) each describe a variety with white seeds and yellow flowers. Such may really exist, but there is no hint of yellow flowers in the 290 varieties we have studied.

Most soy-bean flowers have no perceptible odor; but Nos. 23336, 23337, and 20797, when in full flower at Jackson, Tenn., September 13, 1909, were very fragrant, the odor suggesting that of lilacs.

The flowers are borne on short axillary racemes, commonly with 8 to 16 in each cluster. In some varieties, however, the racemes may have as many as 35 flowers.

PODS.

In most varieties of soy beans the pods are distinctly compressed, but in some cases cylindric, and all possible intermediate forms exist. (See Pls. VI and VII.) The number of seeds per pod in most varieties is 2 to 3. In a few sorts, however, the number is 3 to 4. Wein (Journal für Landwirtschaft, 1881, Supplement (Ergänzungshaft), p. 3) speaks of varieties having occasionally 4 to 5 seeds in a pod, but we have never seen but one example of a 5-seeded pod. The largest pods are perhaps those of No. 23213, 2½ to 3 inches long; the smallest, those of No. 17256, three-fourths inch to 1½ inches long.

Many soy-bean varieties shatter their seeds easily. In general, small pods shatter less easily than large pods, but there are exceptions in each case. Among the varieties tested the Peking, No. 17852B, holds its seeds far better than any other. Plates IV and V show the striking differences in this regard.

Soy-bean pods are commonly borne in clusters of 3 to 5. In a few varieties the clusters may contain 12 pods. Depending on the length of the internodes, the pods appear crowded or scattered. A single plant may bear over 400 pods. The color of the pods may be gray or tawny, or rarely black. Gray pods bear white or grayish hairs, while all tawny pods have tawny pubescence. Certain varieties with black pods bear white or grayish hairs.

SEEDS.

The range in size and shape of soy-bean seeds according to variety is well shown in Plate VIII. None are truly globose, but this shape is closely approximated by some varieties. Others are much flattened. The great majority, however, are elliptic in outline, the thickness less than the breadth.

Most varieties of soy beans have unicolored seeds in the following colors, straw-yellow, olive-yellow, olive, green, brown, and black, the last really a dark violet. Straw-yellow seeds are in some varieties very pale, especially when old, and are sometimes erroneously called white, but no truly white seeds are known in soy beans. In several varieties with straw-yellow seeds, like the Mammoth, the seeds have a greenish tinge if harvested before full maturity, making it difficult to distinguish them from varieties whose fully mature seeds are greenish yellow. The latter again merge by very fine gradations into olive and from this into brown.

Bicolored seeds occur in but few varieties. The commonest are green or yellow with a saddle of black, the latter not sharply delimited. Two varieties have their seeds brindled brown and black, the two colors somewhat concentrically arranged. One variety has black seeds faintly marked with minute brown specks. On heterozygote plants the seeds are often irregularly bicolored, as discussed on another page.

The hilum or seed scar is pale in some varieties and dark in others and therefore often of value to distinguish varieties. In a few varieties, as in Ito San, there is a minute brown spot on the micropyle which is diagnostic.

The germs or embryos of soy-bean seeds are yellow, except in the green-seeded and part of the black-seeded sorts, in which they are green.

FROST RESISTANCE.

Soy beans will withstand considerable frost, both in the spring, when young, and in the fall, when about mature. The trials at the Arlington Experimental Farm, near Washington, D. C., indicated that varieties vary to a considerable degree in this respect. The first frost in the fall of 1909 at this farm came on October 13, the minimum temperature being 31° F. The top leaves of nearly all varieties were slighty touched by this frost. The varieties from India were injured to a greater extent than any of those previously grown. The first killing frost occurred on October 29, 1909, the minimum temperature being 27° F. In the majority of the late and very late varieties the plants were killed. However, several varieties still retained a fair percentage of green leaves, and the pods were but slightly touched. The Riceland and Barchet varieties showed considerable frost resistance, about 50 per cent of the leaves and all the pods remaining green after this later frost. The most resistant variety in the trial was No. 20798E, a selection from No. 20798, Barchet, this variety still having about 70 per cent of green leaves and no pods injured. Those varieties showing any degree of resistance still retained green leaves and pods on November 15, the temperature meantime not reaching the minimum of October 29.

In a variety trial at Muskegon, Mich., in 1909, the Guelph, Ito San, and Ogemaw varieties were found to be quite frost resistant and the

Chernie, Jet, and Meyer extremely sensitive. The comparative resistance of the varieties is reported as follows, the first being least injured: (1) Ogemaw; (2) Haberlandt, Ito San, Kingston, Guelph; (3) Habaro, Shingto, Manhattan, Brindle; (4) Jet; (5) Meyer, Chernie.

It may be that the same variety varies in frost resistance, depending on its stage of maturity. In the foregoing list, however, the Ogemaw, though very early, usually matures with the Manhattan and the Chernie, while the Haberlandt is fifteen days later.

PERIOD OF MATURITY.

In soy beans there is a continuous succession of varieties from very early to very late. With very few exceptions, earliness is correlated with size, the largest varieties being latest. As in the cowpea, early plantings take a longer time to mature than late plantings, but there is by no means a consistent behavior in the different varieties in this respect. In general, the later the variety the more is its life period shortened by later planting.

Haberlandt, in 1877, planted one variety at Vienna at intervals of one week through the season and attempted to correlate the life periods obtained with the amount of heat. His results are shown in Table I.

TABLE I.—*Results of planting a single variety of soy bean at different dates, Vienna, Austria, 1877.*

Date of planting.	Date of harvest.	Life period.	Total heat required— Until germination.	Until blossoming.	Until maturity
		Days.	° *C.*	° *C.*	° *C.*
March 31	September 29	182	230	1,185	2,972
April 7	do	175	294	1,102	2,893
April 14	do	167	189	1,008	2,787
April 21	do	160	217	1,026	2,753
April 28	do	153	228	995	2,701
May 5	October 15	163	209	936	2,811
May 12	do	156	221	960	2,722
May 19	October 18	152	275	1,043	2,641
May 26	do	145	153	985	2,519
June 2	do	138	152	871	2,405
June 9	October 26	139	130	739	2,322

Prof. C. A. Mooers, of the Tennessee Agricultural Experiment Station, has conducted extensive experiments of a similar kind. The following table gives some of his results:[a]

TABLE II.—*Life period of soy-bean varieties planted at intervals of two weeks for two consecutive years at the Tennessee Agricultural Experiment Station.*

Variety.	1907.			1908.		
	Date planted.	Date harvested.	Life period.	Date planted.	Date harvested.	Life period.
			Days.			*Days.*
Mammoth	April 3	October 5	186	April 2	October 7	188
	April 15	do	173	April 14	do	179
	April 30	October 6	160	May 1	do	159
	May 15	October 9	146	May 15	do	145
	June 5	October 12	129	June 1	do	128
	June 17	October 22	127	June 17	October 21	126
	June 29	do	113	July 1	do	112
	July 15	October 28	105	July 16	October 24	100
Medium Yellow	April 3	September 13	164	April 2	August 15	135
	April 15	do	151	April 14	September 7	146
	April 30	do	137	May 1	September 14	136
	May 15	September 18	135	May 15	do	122
	June 5	September 20	107	June 1	September 19	110
	June 17	September 27	102	June 17	September 23	98
	June 29	do	90	July 1	September 28	89
	July 15	October 9	86	July 16	October 17	93
	August 6	October 29	84	August 1	October 24	85
Ito San	April 3	August 9	129	April 2	July 25	114
	April 15	do	117	April 14	July 29	106
	April 30	do	102	May 1	August 5	96
	May 15	August 17	93	May 15	August 15	92
	June 5	September 3	90	June 1	August 27	87
	June 17	September 18	93	June 17	September 10	85
	June 29	do	81	July 1	September 19	80
	July 15	October 9	85	July 16	October 6	82
	August 6	October 29	84	August 1	October 24	85

A large list of varieties has been grown for several years past at the Arlington Experimental Farm, planted each year during the first week in June. In period of maturity nearly all the varieties behave consistently from season to season, as indicated in Table III, on the following page.

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[a] Bulletin 82, Tennessee Agricultural Experiment Station, December, 1908.

TABLE III.—*Life periods of soy beans grown at the Arlington Experimental Farm, near Washington, D. C., for three or four seasons.*

Variety.	1905.			1907.		
	Date planted.	Date harvested.	Life period.	Date planted.	Date harvested.	Life period.
			Days.			*Days.*
No. 14952, Shanghai				June 5	October 20	137
No. 14953, Edward				do.	October 15	132
No. 14954, Acme				do.	do.	132
No. 16789, Brooks				do.	October 7	124
No. 16790, Cloud				do.	do.	124
No. 17251, Buckshot	June 3	September 14	103	do.	September 16	103
No. 17252, Flat King	do.	October 19	128	do.	October 15	132
No. 17253, Nuttall	do.	September 25	114	do.	September 30	117
No. 17254, Ebony	do.	October 3	122	do.	October 6	123
No. 17255, Kingston	do.	September 25	114	do.	September 30	117
No. 17256, Brownie	do.	October 2	121	do.	October 7	124
No. 17257, Eda	do.	September 23	112	do.	September 30	117
No. 17258, Ogemaw	do.	August 30	88	do.	September 15	102
No. 17260, Samarow	do.	September 14	103	do.	do.	102
No. 17261, Guelph	do.	September 23	112	do.	September 30	117
No. 17262, Yosho	do.	September 14	103	do.	September 20	107
No. 17263, Austin	do.	September 30	119	do.	October 10	127
No. 17264, Tokyo	do.	October 30	149	do.	October 20	137
No. 17267, Hope	do.	do.	149	do.	October 21	138
No. 17268, Ito San	do.	September 24	113	do.	September 30	117
No. 17269, Medium Yellow	do.	October 2	121	do.	October 7	124
No. 17271, Haberlandt	do.	September 30	119			
No. 17273, Butterball	do.	September 7	96	June 5	September 30	117
No. 17275, Amherst	do.	September 25	114	do.	October 5	122
No. 17277, Manhattan	do.	September 7	96	do.	September 30	117
No. 17278, Hollybrook	do.	October 14	133	do.	October 20	137
No. 17280, Mammoth	do.	October 28	147	do.	October 25	142
No. 17861, Jet				do.	September 30	117
No. 18227, Chernie				do.	do.	117

Variety.	1908.			1909.		
	Date planted.	Date harvested.	Life period.	Date planted.	Date harvested.	Life period.
			Days.			*Days.*
No. 14952, Shanghai	June 6	October 25	141	June 2	October 30	150
No. 14953, Edward	do.	October 28	144	do.	November 5	156
No. 14954, Acme	do.	October 20	136	do.	October 25	145
No. 16789, Brooks	do.	October 8	124	do.	October 9	129
No. 16790, Cloud	June 9	October 7	120	do.	do.	129
No. 17251, Buckshot	do.	September 16	99	June 7	September 15	100
No. 17252, Flat King	do.	October 15	128	June 2	October 16	136
No. 17253, Nuttall	do.	October 8	121	June 7	October 4	119
No. 17254, Ebony	do.	do.	121	June 2	do.	124
No. 17255, Kingston	do.	October 5	118	do.	do.	124
No. 17256, Brownie	do.	October 8	121	do.	do.	124
No. 17257, Eda	do.	October 1	114	June 7	September 27	112
No. 17258, Ogemaw	do.	September 22	105	do.	do.	112
No. 17260, Samarow	do.	do.	105	do.	do.	112
No. 17261, Guelph	do.	October 5	118	June 2	do.	117
No. 17262, Yosho	June 8	September 21	104	June 7	September 24	109
No. 17263, Austin	do.	October 9	123	June 2	October 16	136
No. 17264, Tokyo	June 6	October 20	134	do.	October 30	150
No. 17267, Hope	do.	do.	134	do.	October 29	149
No. 17268, Ito San	June 8	September 22	106	June 7	October 2	117
No. 17269, Medium Yellow	do.	October 9	123	June 2	October 4	124
No. 17271, Haberlandt	do.	October 5	119	do.	October 9	129
No. 17273, Butterball	do.	September 21	105	June 7	September 27	112
No. 17275, Amherst	do.	October 5	119	June 2	October 4	124
No. 17277, Manhattan	do.	September 14	98	June 7	September 20	105
No. 17278, Hollybrook	June 6	October 12	128	June 2	October 18	138
No. 17280, Mammoth	do.	October 30	146	do.	October 30	150
No. 17861, Jet	June 8	October 10	124	do.	October 9	129
No. 18227, Chernie	June 9	September 30	112	June 7	September 20	105

Based on the data from the Arlington Experimental Farm, the varieties may be classified into seven groups according to their life periods:

Very early	Maturing in 80 to 90 days.
Early	Maturing in 90 to 100 days.
Medium early	Maturing in 100 to 110 days.
Medium	Maturing in 110 to 120 days.
Medium late	Maturing in 120 to 130 days.
Late	Maturing in 130 to 150 days.
Very late	More than 150 days.

CHANGES IN LIFE PERIOD.

Ball, in Bulletin 98 of the Bureau of Plant Industry, page 8, cites the case of Agrostology No. 1299 (S. P. I. No. 17276), obtained from France in 1902, as illustrating that a variety may progressively change from early to late. According to Ball's records, this variety matured at the Arlington Experimental Farm in 1902 in 95 days; in 1903, in 120 days; in 1905, in 130 days. On the other hand, at Knoxville, Tenn., the record of this variety is perfectly consistent from year to year and it matures with the Buckshot, a very early variety.[a] Planted August 2, 1906, both matured in 70 days; planted May 25, 1907, both matured in 91 days; planted July 11, 1907, both matured in 81 days; planted July 30, 1907, both matured in 84 days; planted May 13, 1908, both matured in 80 days; planted July 17, 1908, both matured in 82 days.

No. 1299 was not grown at the Arlington Experimental Farm after 1905 until 1909, when seed was obtained from the Tennessee Agricultural Experiment Station. In this year it matured in 100 days, exactly the same as required for Buckshot that had been grown continuously at Arlington.

It seems difficult to reconcile these results with those reported by Ball, but the subject needs further investigation.

In the case of the Ogemaw variety, phenomena have occurred that are precisely like those reported by Ball. As shown by Table III, this variety required the following periods to mature at the Arlington Experimental Farm: In 1905, 88 days; in 1907, 102 days; in 1908, 105 days; in 1909, 112 days. In all these years the variety remained perfectly uniform and no variants have ever been found in it. In 1909 seed of this variety was secured from several sources to see if any changes in its life period, which was suspected from its increasing lateness at Arlington, had actually occurred. The results are shown in Table IV. All of these lots of the Ogemaw variety came from the same original source, namely, Mr. E. E. Evans, West Branch, Mich.

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[a] Bulletin 82, Tennessee Agricultural Experiment Station, p. 81, 1908.

The limited amount of data concerning three other varieties indicate that Butterball has likewise become later at Arlington or earlier at the Minnesota Agricultural Experiment Station, while no change has taken place in Buckshot and Manhattan.

TABLE IV.—*Variation in life periods of four soy-bean varieties, apparently due to place effect.*

Variety.	Serial No.	Period of maturity at the Arlington Experimental Farm, 1909.	Source of seed.
		Days.	
Ogemaw	0855	84	Minnesota Agricultural Experiment Station, 1908, where grown 5 years from S. P. I. No. 13502 from Agrostology No. 1992.
Do	0854	87	Minnesota Agricultural Experiment Station, 1908, where grown 4 years from Agrostology No. 1992.
Do	0856	87	Minnesota Agricultural Experiment Station, 1908, original seed from Kansas in 1900.
Do	0857	87	Minnesota Agricultural Experiment Station, 1908, original seed from Michigan in 1903.
Do	0858	87	Do.
Do	21755	87	Arlington Experimental Farm, 1908, from seed from Paris, France.
Do	25212	87	Bremen, Germany.
Do	0866	92	Idaho Agricultural Experiment Station, 1908, grown there several years.
Do	0865	97	Idaho Agricultural Experiment Station, 1908, original seed from Minnesota Agricultural Experiment Station, 1907.
Do	17258	112	Arlington Experimental Farm, 1908, where grown for 6 years.
Buckshot	17251	100	Do.
Do	0859	101	Minnesota Agricultural Experiment Station, 1908, grown several years from Agrostology No. 1303.
Do	0860	101	Minnesota Agricultural Experiment Station, 1908, grown several years from Agrostology No. 1979.
Do	0861	101	Minnesota Agricultural Experiment Station, 1908, grown several years from Agrostology No. 1978.
Manhattan	17277	105	Arlington Experimental Farm, 1908, where grown for 6 years from Agrostology No. 1295.
Do	0862	105	Minnesota Agricultural Experiment Station, 1908, where grown for several years from Agrostology No. 1295.
Do	8422	117	Arlington Experimental Farm, 1908, from seed grown several years at Illinois Agricultural Experiment Station from Agrostology No. 1199.
Butterball	0863	105	Minnesota Agricultural Experiment Station, 1908, where grown for several years from Agrostology No. 1197.
Do	0864	105	Minnesota Agricultural Experiment Station, 1908, where grown for several years from Agrostology No. 1199.
Do	17273	112	Arlington Experimental Farm, 1908, where grown for 6 years from Agrostology No. 1197.

POLLINATION AND HYBRIDIZATION.

The soy-bean flower is completely self-fertile, bagged plants setting pods as perfectly as those in the open. This was tested at the Arlington Experimental Farm in 1909 by bagging 30 plants representing 10 varieties. In no case did the bagged individuals fail to produce as well as neighboring unbagged plants. Ten plants were also inclosed in box screens with similar results.

The flowers are much visited by bees, mainly for the pollen, as but a very small quantity of nectar is secreted. Cross-pollination would be of frequent occurrence were it not that the abundant pollen of each flower covers the stigma almost as soon as the flower opens.

Previous to 1907 the remarkable uniformity of the plats at the Arlington Experimental Farm, except for occasional and evident admixtures, had led to the belief that natural hybrids of the soy bean did not occur. In that year the occurrence of certain oddly colored seeds, smoky green, smoky yellow, brown and yellow, etc., in the bulk seed was noted. These were carefully saved and the resultant rows in 1908 gave diverse progeny, showing that some of the seeds at least were hybrids. In 1908 more than a hundred single-plant selections of supposed hybrids were made and planted in 1909. Some of the results are indicated in Table V.

TABLE V.—*Variations in hybrid soy-bean plants and their progeny at the Arlington Experimental Farm, 1908–1910.*

Hybrid.			Progeny.			
Serial No.	Color of pubescence.	Color of seed.	Total number of plants.	Color of pubescence.	Color of flower.	Color of seed.
1826	Tawny	Cloudy green	50	Tawny	Purple	Green, 39; black, 10; cloudy green, 1.
[illegible]	do	Olive-yellow	44	Tawny, 32; gray, 12	White	Olive-yellow.
[illegible]	do	do	42	Tawny	Purple	Olive-yellow with black hilum, 2; olive-yellow with seal-brown hilum, 40.
[illegible]	do	do	22	Tawny, 18; gray, 4	Some purple, some white	Varying from straw-yellow to olive-yellow.
[illegible]	do	Black with brown specks	32	Tawny, 27; gray, 5	Purple	Black with brown specks, 20; black, 8; brown, 4.
[illegible]	Gray	Olive-yellow	40	Gray, 38; tawny, 2	Some purple, some white	Olive-yellow.
[illegible]	do	Straw-yellow	33	Gray, 32; tawny, 1	White	Straw-yellow.
17253 C-1	do	Olive-yellow	8	Tawny, 7; gray, 1	do	Olive-yellow, 3; brown, 5.
17253 C-[illegible]	Tawny	Black	8	Tawny	Purple	Black, 7; black and brown, 1.
17253 C-4	do	Brown	13	Tawny, 10; gray, 3	do	Dark brown, 9; light brown, 3; black, 1.
17253 C-5	do	Olive to brown	18	Tawny	Some purple, some white	Green, 1; olive to brown, 17.
17253 C-6	do	Straw-yellow	38	do	do	Straw-yellow, 28; brown, 10.
17253 C-7	do	Olive to brown	40	do	do	Black, 2; olive to brown, 38.
17253 C-8	do	do	30	Tawny, 25; gray, 5	do	Light brown, 5; olive-green, 25.
17255 A	do	Green	28	Tawny	do	Green, 22; black, 5; cloudy green, 1.
17257 A-1	do	Brown	103	do	do	Brown, 101; green, 1; greenish brown, 1.
17257 A-2	do	Black	68	Tawny, 56; gray, 12	do	Black, 54; brown, 12; olive, 2.
17257 A-9	do	Olive-yellow	26	Tawny, 19; gray, 7	White	Olive-yellow, 23; black, 3.
17257 A-10	do	Brown	21	Tawny, 17; gray, 4	do	Reddish-brown, 17; light brown, 4.
17262-1	do	Olive-yellow	50	Tawny, 37; gray, 13	do	Olive-yellow, dark hilum, 37; pale hilum, 13.
17263 B-1	do	do	96	Tawny, 75; gray, 21	do	Olive-yellow.
17277 C	do	Brown	58	Tawny, 42; gray, 16	Purple	Dark brown, 42; light brown, 16.
17852 L-1	do	Straw-yellow	72	Tawny	Purple, 56; white, 16	Straw-yellow, 54; brown and black, 14; brown, 4.
17852 L-2	do	Olive-yellow	85	do	Purple	Olive-yellow, 74; brown and black, 10; black, 1.
17852 L-3	do	Black and brown	81	do	do	Black and brown, 54; brown, 26; black, 1.
17852 L-4	Gray	Brown	85	Gray, 84; tawny, 1	Some purple, some white	Yellow, 2; light to dark brown, 83.
17852 L-7	Tawny	Black and brown	77	Tawny	do	Black and brown, 40; brown, 36; yellow, 1.
22379-2	do	Straw-yellow	78	Tawny, 52; gray, 26	Purple	Straw-yellow, brown and yellow.
22411 A-2	do	Black and olive	26	Tawny	do	Black, 19; brown to olive, 7.
25161-1	do	Straw-yellow	55	do	do	Brown, 42; straw-yellow, 13.

It is evident from the diversity of the progeny that the parents were hybrids in all the cases listed. The number of plants grown in each case is too small to secure definite proportions, but it is clear that the color of the pubescence and the color of the seed behave in Mendelian fashion. The same is probably true of the flower color, which was counted in only one case.

There is thus furnished a clear explanation of the origin of many of the new varieties at the Arlington Experimental Farm that were at first mistaken for accidental admixtures. It also accounts for the diversity of the population exhibited in many introduced varieties notwithstanding the apparent uniformity of the seed.

It must not be supposed from the foregoing account that hybrids are common in soy beans. At Arlington the test rows are grown contiguously, so that there is great opportunity for cross-pollination. Nevertheless, the percentage of hybrids that occur is very small, perhaps not one individual in two hundred.

Thus far the hybrid plants have been detected mostly by the color of the seed. In a number of cases none of the progeny has seed similar to the parent; or, in other words, the color of heterozygote seeds is often unstable. Among the most striking of such heterozygote seeds (Pl. VIII) are yellow with a single narrow transverse band of brown; yellow or green, with an irregularly star-shaped brown or black figure centering at the hilum; and green or yellow more or less suffused with a smoky color. Some of the last breed true, but most of them do not.

Heterozygote plants, especially where the seeds are largely or wholly yellow, are often distinguishable by the unusual form of the pods near the tips of the branches. These are more tumid than the other pods and the seeds more crowded. Such pods may also be thinner in texture and much less hairy. Illustrations of this phenomenon are shown in Plate VII.

MUTATIONS.

The origin of new varieties of soy beans without hybridization has apparently occurred in certain cases that have come under our observation. From a theoretical standpoint there can be no doubt that the fundamental diversity in a plant, especially when normally self-pollinated, is brought about by other causes than hybridization. It is self-evident that there must be two different varieties to cross before crossing can become effective in producing new varieties. Most soy-bean varieties when pure remain very constant to type, so that any chance variation is quickly detected. There are two cases in which the evidence is fairly satisfactory that a brown-seeded variety arose as a mutation from a yellow-seeded sort.

Trenton (S. P. I. No. 24610).—This is a brown-seeded variety found by Mr. S. J. Leavell, of Trenton, Ky., in a field of the yellow-seeded Mammoth. Grown side by side at the Arlington Experimental Farm in 1909, the two varieties were indistinguishable by any other character than the seed color.

Riceland (S. P. I. No. 20797).—At the Arlington Experimental Farm this variety has been grown for three seasons, and while it matures but few seeds it is very uniform. At Biloxi, Miss., in 1908, it displayed astonishing diversity. Some plants had very narrow leaves, others very broad, and all degrees of intermediates occurred; some plants were erect, others procumbent; some fruited heavily, others scarcely at all. The seed was saved from individual plants showing the most striking variations, and the resultant plants of each in 1909 were uniform. It is possible that the seed planted at Biloxi contained these forms, but the fact that the same bulk seed gave uniform plants elsewhere indicates that the diversity was a response to the environment. No similar phenomenon has as yet been witnessed in other varieties.

NOMENCLATURE AND CLASSIFICATION.

Most of the varieties of soy beans that were early introduced into the United States received such names as Early Black, Medium Green, Late Yellow, etc., one adjective referring to the period of maturity, the other to the color of the seed. As long as the varieties were few such a system of naming was satisfactory.

In 1907, when the number of varieties had increased to 23, Ball[a] recognized the impracticability of such a system of nomenclature and gave single-term appellations to most of the varieties. On this account, several of the older sorts are now known by two or more names.

At the present time there are known about 300 varieties, mostly obtained in the last three years from Asia by the activities of the Office of Seed and Plant Introduction of the Bureau of Plant Industry. In the synopsis of the varieties here presented they are classified (1) by the type of plant into five groups and (2) by the color of the seeds. A brief description is given of each, but only the more important have been given names. It will be noticed that a considerable number of the varieties are not pure, containing two or more closely similar sorts distinguished by the color of the flowers or the color of the pubescence, or both. Thus, the Acme variety is really a mixture of four sorts, namely, white flowered with gray pubescence, white flowered with tawny pubescence, purple flowered with gray pubescence, and purple flowered with tawny pubescence. These all mature together and the seeds are either identical or distinguishable with great difficulty. Nevertheless, the results secured with other varieties leave no question that all these can be separated and bred true to type.

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[a] Bulletin 98, Bureau of Plant Industry, 1907.

In regard to the brief descriptions given, a few words of explanation are necessary. Many of the importations proved to be impure lots of seeds. In some cases, especially where the seeds were differently colored, these were separated before planting, and such are definitely indicated. In other cases the mixture was not detected until the plants were grown, or, in a few cases, until the seed was harvested. Where the difference was detected in the field and the plants separated, they are referred to as "field selections." On the other hand, if the selection was merely a separation of seed from the garnered crop, these are spoken of as "seed selections." Both the "seed" selections and the "field" selections are for the most part "mass" selections, and many of them prove still to be impure, containing both tawny and gray-haired, or red-flowered and white-flowered varieties, which, however, mature together. Most of these have not been separated, though in all valuable varieties they should be. Where one or the other of such differences is not recorded, the variety is a pure strain. Where the selections were made the first year that the plants were grown from imported seeds, they may be either accidental admixtures or the result of hybridization at the place where the original seed was grown. If, on the other hand, they were selected two or more years after they were introduced, they are almost certainly the result of hybridization at the Arlington Experimental Farm.

Besides these, many individual or centgener selections have been made; these, however, are not considered in the accompanying descriptions. Except these last, all selections are indicated by the original S. P. I. serial number with a letter added, thus 16790 D.

It will be apparent from the descriptions that many varieties are very similar to one another. Only a comparatively few of them have been named. Very careful field comparisons were made, however, in all cases, so that each description represents a different thing.

In the cases of a number of early S. P. I. introductions, new numbers were assigned to different lots of seed grown from the original. Thus, the original introduction of Ebony was S. P. I. No. 6386 and different lots of its progeny were Nos. 8492, 9414, and 17254. This is indicated in each case. Many of these earlier S. P. I. numbers were also distributed under a series of Agrostology numbers, full keys to their respective identities being given by Ball in Bulletin 98 of the Bureau of Plant Industry, so that their identity with the numbers and descriptions here given can be easily determined.

EARLY AGRICULTURAL HISTORY IN THE UNITED STATES.

The first mention of the soy bean in American literature is by Thomas Nuttall, in the New England Farmer, October 23, 1829. Nuttall grew a variety with red flowers and chocolate-brown seeds in the botanic garden at Cambridge, Mass., and from his observations wrote a brief account concerning it. He writes:

> Its principal recommendation at present is only as a luxury, affording the well-known sauce, soy, which at this time is only prepared in China and Japan.

In the same journal two years later, November 23, 1831, is an account of the successful culture of the plant at Milton, Mass., the seed having been obtained from Nuttall.

No further mention of the plant in American literature appears until 1853, when a brief account appeared under the name "Japan pea," by A. H. Ernst, Cincinnati, Ohio, as follows: [a]

> The Japan pea, in which so much interest has been manifested in this country for a year or two past, from its hardihood to resist drought and frost, together with its enormous yield, appears to be highly worthy of the attention of agriculturists.
>
> This plant is stated to be of Japan origin, having been brought to San Francisco about three years since, and thence into Illinois and Ohio. Its habit of growth is bushy, upright, woody, and stiff, branching near the ground, and attaining a height of three or four feet. The leaflets are large, resembling those of an ordinary bean, occurring in sets of three, with long quadrangular stems. The flowers, which are small and white, but rather inconspicuous, sometimes having purple centers.

In the following year, 1854, the Perry expedition brought back two varieties of "soja bean" from Japan, one "white" seeded, the other "red" seeded.[b] These, together with the Japan pea, were distributed by the Commissioner of Patents in 1854, and, thereafter, frequent references to the plant occur in agricultural literature under such names as Japan pea, Japan bean, and Japanese fodder plant.[c] Most of these articles speak of the plant as the Japan pea, none of them as the soy or soja bean. It is apparent from the early accounts that there were at least two Japan peas, one early enough to mature in Connecticut (Patent Office Report, 1854, p. 194), the other very late (American Agriculturist, 1857, vol. 16, p. 10). Judging from all the accounts, we suspect that the early Japan pea may be the Ito San variety, which, however, has red flowers, while the late variety may be the Mammoth. The Ito San is still occasionally called the Japan pea, while the introduction and source of the Mammoth has never been definitely determined. From these early accounts the Mammoth may well be the "white-seeded" soja bean obtained by the Perry expedition. The "red-seeded soja bean" was perhaps, the Adsuki bean (*Phaseolus angularis*), as no red-seeded soy bean is known.

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[a] Report of the Commissioner of Patents, Agriculture, p. 224.

[b] Report of the Commissioner of Patents, Agriculture, 1854, p. xv.

[c] See especially Report of the Commissioner of Patents, Agriculture, 1854, p. 194. American Agriculturist, November 1, 1854, p. 120; January, 1857, p. 10; February, 1874, p. 63. Rural New Yorker, January 21, 1854, p. 22; January 21, 1858, p. 14. American Farmer, January, 1856, p. 57. The Cultivator, May 18, 1855.

Prof. G. H. Cook, of New Brunswick, N. J., obtained seed of the soy bean at the Bavarian Agricultural Station in 1878. In the same year Mr. James Neilson[a] obtained seeds of several varieties at Vienna, Austria. Both of these gentlemen planted the seeds and gathered crops of the different varieties in 1879. These varieties were without doubt those grown and distributed through Europe by Professor Haberlandt, of Vienna.

A yellow-seeded soy bean was grown at the North Carolina Agricultural Experiment Station in 1882 and reported on in some detail. The source of the variety is not given, but by implication it is the same as the variety stated to be grown by a number of persons in the State, and is probably the Mammoth.[b]

Two varieties, one black seeded, the other with white seeds, were grown at the Massachusetts Agricultural Experiment Station in 1888.[c]

In 1890 Prof. C. C. Georgeson secured three lots of soy beans from Japan which were grown at the Kansas Agricultural Experiment Station in 1890 and subsequently.[d]

Prof. W. P. Brooks, of Amherst, Mass., brought with him from Japan in 1889 a number of soy-bean varieties, including the Medium Green or Guelph, and the Ito San. It is quite certain that other importations of soy beans from Asia were made by others, but no definite records have been found.

Since 1890 most of the agricultural experiment stations have experimented with soy beans and many bulletins have been published dealing wholly or partly with the crop.

VARIETIES INTRODUCED INTO THE UNITED STATES INDEPENDENTLY OF THE DEPARTMENT OF AGRICULTURE OR PREVIOUS TO 1898.

ENUMERATION.

Previous to the numerous introductions by the United States Department of Agriculture beginning in 1898, there were not more than eight varieties of soy beans grown in the United States, namely, Ito San, Mammoth, and Butterball, with yellow seeds; Buckshot and Kingston, with black seeds; Guelph or Medium Green, with green seeds; and Eda and Ogemaw, with brown seeds.

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[a] Rural New Yorker, 1882, p. 9.

[b] Annual Report of the North Carolina Experiment Station, 1882, pp. 116-127.

[c] Annual Report of the Massachusetts Experiment Station, 1889, pp. 140-141.

[d] Bulletin 19, Kansas Agricultural Experiment Station, p. 200.

It has been possible to determine the history of these, in part at least, which is of value in interpreting the older records.

ITO SAN.

Ito San was among the varieties introduced in 1899 by Prof. W. P. Brooks, of Amherst, Mass., and by him called Early Yellow. Later, Mr. E. E. Evans secured seed of it and in 1902 called it Ito San. Mr. Evans writes that he subsequently secured it "from half a dozen sources in the United States and Japan." The same variety was also among those introduced by Prof. C. C. Georgeson, of the Kansas Agricultural Experiment Station, and grown in 1890 [a] and subsequent years. This conclusion is based on the identity of nine varieties obtained from the Rhode Island Agricultural Experiment Station in 1903. This station had previously obtained several varieties from the Kansas Agricultural Experiment Station in 1892.[b] Three of the varieties from Rhode Island had exactly the same names as those published in Bulletins 19 and 32 of the Kansas Agricultural Experiment Station, namely, Eda Mame, Yellow Soy Bean, and Kiyusuke Daidzu. All three of these are Ito San.

Ball [c] gives a list of numerous American sources through which this variety was secured under such names as Yellow, Early Yellow, and Early White. It was also grown at the Virginia Agricultural Experiment Station in 1905 as Japanese pea, as shown by later cultures at the Arlington Experimental Farm of seed from this experiment station.

Among the introductions of the Office of Foreign Seed and Plant Introduction it is represented by No. 6326, received in 1901 from Tokyo, Japan, and No. 21818, obtained from Vilmorin-Andrieux & Co., Paris, France, as "Yellow Etampes." It is quite probable that this is one of the varieties grown by Professor Haberlandt in his experiments, as all of his varieties were grown at Etampes and other places in France.[d] We suspect that this is also the variety that was distributed by the United States Patent Office in 1853, as most of the early accounts point to this or a closely similar variety. These accounts refer to it as Japan pea, Japanese pea, Japan bean, and also coffee berry.[e]

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[a] Bulletin 19, Kansas Agricultural Experiment Station, December, 1890.

[b] Report, Rhode Island Agricultural Experiment Station, 1892, p. 150.

[c] Bulletin 98, Bureau of Plant Industry, p. 24.

[d] La Nature, 1881, pt. 2, p. 115.

[e] See especially the Rural New Yorker, January 21, 1854, p. 22.

MAMMOTH.

The Mammoth is at present the most important soy bean grown in the United States. It has also been known as Late, Yellow, Late Yellow, Southern, and Mammoth Yellow.

The date of introduction of this variety is very obscure, and nothing definite is known regarding its origin. None of the numerous recent introductions are identical and but one is closely similar, namely, No. 22318, from Erfurt, Germany, received as "Yellow Riesen." It is not probable, though, that this was German-grown seed, as so late a variety could scarcely mature in Germany. Several varieties from Shanghai, China, and from Japan are closely related. It may possibly be the "white-seeded" soy bean introduced by the Perry expedition. We have been unable to find any early published records that definitely refer to this variety. It is not improbable that it is this variety that was grown at the North Carolina Agricultural Experiment Station in 1882. There can be but little doubt that it is the "soja" bean from T. W. Wood & Sons, Richmond, Va., grown by the Kansas Agricultural Experiment Station in 1889 [a] and in 1890.[b] Since 1895 Mammoth has been a well-known variety.

BUCKSHOT.

The history of this variety is somewhat complicated. It has been obtained from the following American sources:

Agrostology No. 1184, "Black," from Rhode Island Agricultural Experiment Station, spring, 1903.

Agrostology No. 1301, "Early," from Johnson & Stokes, March, 1902.

Agrostology No. 1303, "Extra Early Black," from J. M. Thorburn & Co., March, 1902.

Agrostology No. 1304, from W. A. Burpee, March, 1902.

Agrostology No. 1474, "Extra Early Black," from Hammond Seed Company, March, 1903.

Agrostology No. 2033, "Crossbred No. 9," from the Arkansas Agricultural Experiment Station, May, 1904. "Crossbred No. 9" of Evans is really Ogemaw, while his "Crossbred No. 6" is Early Black or Buckshot. These two numbers were exactly reversed at the Arkansas Experiment Station, as the variety received from that station as "Crossbred No. 6" (Agrostology No. 2031) proved to be Ogemaw.

All of the foregoing were later united as S. P. I. No. 17251.

S. P. I. No. 6334, from Tokyo, Japan, April 20, 1901. Among the progeny of this are S. P. I. Nos. 8491, 9412, and probably 11179, and Agrostology No. 1292.

S. P. I. No. 19987, from Yokohama, Japan, 1907.

S. P. I. No. 22883, from Tokyo, Japan, 1908.

S. P. I. No. 22322, "Early Black from Podolia," Haage & Schmidt, 1908.

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[a] Report, Kansas Agricultural Experiment Station, 1889, p. 43.

[b] Bulletin 19, Kansas Agricultural Experiment Station, p. 201.

From these data it would appear that the Buckshot is a common Japanese variety. But Mr. E. E. Evans, West Branch, Mich., claims that this variety was originated by him in 1901 as a hybrid, "Evans's Crossbred No. 6," which he advertised in 1902 and distributed widely. In recent correspondence Mr. Evans states that this was a hybrid of a large, flat, black variety, Medium Early Black, and of the Dwarf Brown. According to Mr. Ball, No. 6334 and its progeny numbers were identical with Evans's variety. In Mr. H. T. Nielsen's opinion, Nos. 19987 and 22883 were also precisely identical. Unfortunately, these three Japanese lots were not grown in 1909. A critical comparison of the seed samples shows, however, that the three Japanese lots have thicker, more nearly globose seeds than most of the lots derived from Evans's plant. It is, therefore, not unlikely that there are really two closely similar but distinct varieties involved, a matter which needs further investigation.

Nos. 22322 and 25212 A are undoubtedly the same as Evans's plant.

GUELPH, OR MEDIUM GREEN.

Guelph, or Medium Green, was introduced by Prof. W. P. Brooks, in 1889, from Japan, and is now quite extensively grown in the Northern States. The same variety was also obtained from Hankow, China, in May, 1901—S. P. I. No. 6558, according to Ball's identification.[a] It has since been received from only one foreign source, namely, S. P. I. No. 22320, from Haage & Schmidt, as "Green Samarow." This last might easily be the progeny of the American introduction.

BUTTERBALL.

The Butterball variety was first secured from the Rhode Island Agricultural Experiment Station in 1903 as "Early Japan," and it is probably one of Professor Brooks's introductions. According to Ball,[b] S. P. I. No. 8422, from Yokohama, Japan, is identical. A recent culture of this number obtained after a lapse of several years from the Illinois Agricultural Experiment Station, through Mr. H. B. Derr, proved to be Butterball, but there were a few different things intermixed, probably hybrids. A recent lot of seed from Dammann & Co., Naples, Italy, S. P. I. No. 22415, received as "Giant Yellow," is undoubtedly Butterball.

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[a] Bulletin 98, Bureau of Plant Industry, p. 21.

[b] Bulletin 98, Bureau of Plant Industry, p. 25.

KINGSTON.

The Kingston soy bean was received from the Rhode Island Agricultural Experiment Station in 1903 as "Japanese No. 15." It was obtained by them from Prof. W. P. Brooks, of the Massachusetts Agricultural Experiment Station, who brought a number of soy-bean varieties from Japan in 1889, and is probably the variety which he named "Medium Black." It has never been secured from any other source. In all probability this is the variety grown at the Rhode Island Agricultural Experiment Station in 1893[a] as "Medium Black."

SAMAROW.

The Samarow has not occurred in any of our Asiatic importations. It is advertised under the name of "Green Samarow" by several European seedsmen. Messrs. J. M. Thorburn & Co., who first introduced it into the United States about 1901, inform us that their seed was from Italy. The "Green Samarow," S. P. I. No. 22320, from Haage & Schmidt, Erfurt, Germany, proved to be Guelph.

EDA.

The Eda is the brown-seeded variety introduced from Japan and grown by the Kansas Agricultural Experiment Station in 1890 under the name *Yamagata Cha-daidzu.* The identification of Chadaidzu rests on the fact that the Rhode Island Agricultural Experiment Station secured all of the varieties from Kansas in 1892. The Department of Agriculture obtained all of these varieties from Rhode Island in 1903, including but one brown-seeded variety under the name "Brown Eda Mame."

OGEMAW, OR OGEMA.

The Ogemaw, or Ogema, variety was first introduced by Mr. E. E. Evans, of West Branch, Mich., in 1902, as "Evans's Crossbred No. 9." Mr. Evans writes that he originated this as a cross between his No. 6, Early Black, and the Dwarf Brown. All of the several lots of this variety grown in our trials, namely, Agrostology Nos. 13502, 17258, and 17259, trace back to this origin, and it has been obtained from no foreign source. Nos. 21755, from France, and 25212, from Bremen, Germany, are very similar, however.

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[a] Annual Report, Rhode Island Agricultural Experiment Station, 1893, p. 191.

VARIETIES GROWN IN EUROPE.

EARLY HISTORY.

The growing of soy beans in Europe dates from the experiments of Prof. Friedrich Haberlandt, of Vienna, in 1875 and subsequent years. Haberlandt secured seed of nineteen varieties at the Vienna exposition in 1873. These were as follows:

Five yellow-seeded varieties from China.
Three black-seeded varieties from China.
Three green-seeded varieties from China.
Two brown-red-seeded varieties from China.
One yellow-seeded variety from Japan.
Three black-seeded varieties from Japan.
One black-seeded variety from Trans-Caucasia.
One green-seeded variety from Tunis.

Of these, only four varieties matured at Vienna, namely, two yellow seeded, one black seeded, and one brown-red seeded, all from China. All of Haberlandt's further work was done with these four varieties, which were grown in many places in Austria and Germany and in France and Italy, so that they became widespread. Presumably they are still among the varieties grown in Europe. They were brought to this country by Cook and by Neilson in 1878,[a] but it is only by surmise that any of the American varieties can be traced to this source.

From various European sources the following varieties of soy beans have been obtained:

SAMAROW.

Seed obtained from Dammann & Co., Naples, Italy, No. 22411, and identical with No. 17260, which last was introduced by Messrs. Thorburn & Co. from Italy. Also called "Green Samarow."

ETAMPES.

Seed from Vilmorin-Andrieux & Co., Paris, France, No. 21818, proved identical with Ito San. Also advertised by other European seedsmen, usually as Yellow Etampes.

CHERNIE.

Seed was received from Vilmorin-Andrieux & Co. as "Early Black from Podolia," No. 21757 and No. 21756; from Haage & Schmidt, Erfurt, Germany, as No. 22321; and from Dammann & Co. as "Black," No. 22412. All of these are identical and indistinguishable from No. 18227, obtained from Khabarovsk, Siberia.

"YELLOW RIESEN."

Seed obtained from Haage & Schmidt, No. 22318. The variety is very similar to Mammoth, but somewhat later. No. 22317, "Yellow," from the same source, has indistinguishable seeds, but these did not germinate.

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[a] Rural New Yorker, 1882, p. 9.

BUCKSHOT.

No. 22322, obtained from Haage & Schmidt, is indistinguishable from the Buckshot variety, S. P. I. No. 17251. It was received as "Early Black from Podolia," but is not the same as the variety received under that name from another source. Seeds of this variety were also mixed in the brown seed from the Botanical Garden of Bremen, Germany, and grown as No. 25212 A.

"YELLOW."

This variety was received from Dammann & Co., No. 22414, and Vilmorin-Andrieux & Co., No. 21754, the two being identical and different from any others yet received. It is a small, early variety, maturing at Arlington in ninety days.[a]

"BROWN."

Seed under this name was obtained from Dammann & Co., No. 22413, Haage & Schmidt, No. 22319, and Vilmorin-Andrieux & Co., No. 21755. These seeds are indistinguishable, but only No. 21755 grew. The original seed of this is much smaller than Ogemaw, but in 1909 both the seeds and plants could not be distinguished from Ogemaw from Michigan. No. 25212, from the Botanical Garden, Bremen, Germany, also with brown seeds, was likewise indistinguishable from Ogemaw in 1909, though the original seeds were different both from No. 21755 and from Ogemaw.

BUTTERBALL.

The variety secured from Dammann & Co., No. 22415, as "Giant Yellow," could not be distinguished from S. P. I. No. 17274, Butterball.

S. P. I. NO. 5039.

This seed was received from Vilmorin-Andrieux & Co. as "Extra Early Black Seeded." This is the original importation of the variety later named Wisconsin Black, S. P. I. No. 25468, which is now commercially handled by a few seedsmen.

There are no authentic records of a few of the earliest S. P. I. importations from Europe, so that nothing definite can be said as to their identity. Among these are No. 1492 (brown seeded), No. 1493 (black seeded), and No. 2156, Yellow Etampes, all from France.

From these data it would appear that at the present time at least ten varieties of soy beans are more or less grown in Europe. Presumably there are included among these the four varieties grown by Haberlandt, and it is therefore probable that his black variety was Chernie, his brown-red variety the "Brown" of the European seedsmen, one of the yellows the Ito San or Etampes, and the other probably the "Yellow" of Dammann & Co. and Vilmorin-Andrieux & Co. All of these are quite small seeded and agree well with the weights per thousand seeds as given by Haberlandt.

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[a] No. 17276, without name, from Havre, France, is a very similar but distinct variety.

THE SOY BEAN IN ASIA.

ASIATIC SOURCES OF SOY BEANS.

Soy beans are grown most abundantly in Asia in Japan, Korea, Manchuria, and in the northern provinces of China, namely Shan-si and Shan-tung, but little detailed statistical information concerning the crop has yet been published.[a]

In other provinces of China the plant seems not to be cultivated extensively, though grown as far south as the Yangtse. Seeds have also been received from such places as Canton and Hongkong in southern China, but it is not certain that these were grown there. The soy bean is also grown sparingly in Formosa, Cochin China, Celebes, Java, and India.

According to Watt[b] the soy bean is "extensively cultivated throughout India and in eastern Bengal, Khasi Hills, Manipur, the Naga Hills, and Burma, often found as a weed on fields or near cultivation." The few varieties secured from India are very distinct, indicating a long culture in that country, as indeed the numerous vernacular names used would imply.

LIST OF VARIETIES.

Among the many varieties introduced it is a very interesting fact that the same variety has rarely been secured a second time unless from the same place. It appears that practically every locality in China has its own local varieties. If this be true, then there are probably several times as many varieties existing as have yet been obtained. In general, the earliest varieties come from the northernmost localities, the latest from the southernmost.

The following lists show the various places in Asia from which soy-bean seed has been obtained. Distinct soy-bean varieties are obtained from practically every different locality. The list not only indicates to some extent the distribution of the soy bean, but will suggest the more likely regions from which valuable new varieties may be obtained.

SIBERIA.

South Usuri, Nos. 480, 20699; Khabarovsk, Nos. 18227, 20405, 20406, 20408; Merkoechofka, Nos. 20407, 20409, 20410, 20411, 10412, 20414.

MANCHURIA.

Newchwang, Nos. 19183, 19184, 19186; Harbin, No. 20854; Tieling, Nos. 21079, 21080.

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[a] See, however, the following works: Hosie, Alexander, Report on the Province of Szechwan, 1904, and Soya Bean and Products; Special Consular Reports, vol. 40, 1909, Bureau of Manufactures, Department of Commerce and Labor.

[b] Dictionary of the Economic Products of India, 1890, vol. 3, p. 510.

KOREA.

Pingyang, Nos. 6386, 6396, 6397, 6414, 6416; Ko-bau, No. 20011.

JAPAN.

Tokyo, Nos. 647, 648, 650, 651, 652, 653, 654, 655, 656, 6312, 6314, 6326, 6333, 6334, 6335, 6336, 22874, 22875, 22876, 22877, 22878, 22879, 22880, 22881, 22882, 22883, 22884, 22885; Kobe, Nos. 20892, 20893; Yokohama, Nos. 4980, 8422, 8423, 8424, 19981, 19982, 19983, 19984, 19985, 19986, 19987, 22503, 22504, 22505, 22506, 22507; Hokkaido, Nos. 21825, 21830, 21831; Anjo, No. 8900.

CHINA.

Peking, Chihli, Nos. 17852, 23305, 23306, 27498; Shan-hai-kwan, Chihli, No. 17857; Tientsin, Chihli, Nos. 17862, 23229; Paotingfu, Chihli, Nos. 22897, 22899, 22900, 22901, 23312; Wutaishan, Chihli, Nos, 23291, 23292; Shiling, Chihli, Nos. 23303, 23311; Pee-san, Chihli, No. 18258; Tschang-ping-tsu, Chihli, No. 18259; Sachon, Chihli, No. 17861; Chefoo, Shantung, Nos. 22536, 22537, 22538; Boshan, Shantung, No. 21999; Chungking, Szechwan, Nos. 23522, 23523; Ningyuenfu, Szechwan, Nos. 23544, 23545, 23646; Yachow, Szechwan, Nos. 25437, 25438; Soochow, Kiangsu, Nos. 23207, 24180, 24181, 24182, 24183, 24184, 25133, 25134, 25135, 25136, 25137, 25138; Shanghai, Kiangsu, Nos. 14952, 14953, 14954, 18619, 22311, 22312, 22927, 23205, 23336, 23337, 23338; Chinhuafu, near Shanghai, Nos. 20797, 20798, 23232; Chin-kiang, Kiangsu, Nos. 8584, 8586; Chinhua, Kiangsu, No. 9344; Tangsi, Chekiang, Nos. 23208, 23209, 23211; Taichow, Chekiang, Nos. 23296, 23297; Hangchow, Chekiang, Nos. 16789, 16790, 22498, 22499, 22500, 22501, 22644, 22645, 22646, 23212, 23213; Hankow, Hupeh, Nos. 6556, 6558, 6559, 6560, 6561; Wuchang, Hupeh, Nos. 2869, 2870, 2871, 2872; Ingchung, Fukien, Nos. 22920, 22921, 22922; Ingang, Fukien, No. 27499; Swatow, Kwangtung, No. 22886; Canton, Kwangtung, Nos. 22379, 22380, 23325, 23326, 23327; Hongkong, Kwangtung, Nos. 22406, 22407; Sheklung, Kwangtung, Nos. 22633, 22634; Tsintse, Anhwei, No. 23299; Weihsien, Shantung, Nos. 22534, 22535.

FORMOSA.

Taihoku, Nos. 24641, 24642, 24643.

COCHIN CHINA.

Saigon, No. 22714.

INDIA.

Darjiling, Assam, Nos. 24673, 24674; Pithoragarh, Kumaon District, No. 25118; Khasi Hills, Assam, No. 24672; Safipur, Unao, U. P., No. 24675; Hasangani, Unao, U. P., No. 24676; Ranjitpurwa, Unao, U. P., No. 24677; Etawah, U. P., Nos. 24678, 24679, 24680, 24683, 24684, 24685, 24686; Mainpuri, U. P., Nos. 24681, 24682; United Provinces, No. 24687; Cawnpore, U. P., Nos. 24688, 24689; Dehra Dun, U. P., No. 24690; Poona, Bombay, but grown there from Japanese seed, Nos. 24693, 24694, 24695, 24696, 24697, 24698, 24699, 24700, 24701, 24702, 24703, 24704, 24705, 24706, 24707, 24708, 24709, 24710, 24711.

JAVA.

Buitenzorg, No. 21946.

CELEBES.

Macassar, Celebes, No. 5517.

DESIRABLE CHARACTERS IN SOY-BEAN VARIETIES.

CONSIDERATIONS GOVERNING CHOICE.

The determination of the best variety of soy bean for any locality will depend first on whether it is grown primarily for hay or for grain, or for both purposes. In this, as with other crops, yield is the most valuable single desideratum. Secondary considerations of importance are habit of the plant, degree of coarseness, ability to retain the foliage, color of seed, and ease of shattering.

HABIT OF THE PLANT.

Erectness of stem with upright or ascending branches is a prime requisite of a desirable variety. A tall habit is also important, as dwarf varieties usually bear pods very close to the ground, so that many will be left on the stubble, which is not the case in many tall sorts.

COARSENESS.

An objection to some varieties of soy beans is the coarse, woody stem which makes mowing difficult. There are many slender varieties where this objection does not hold, but slenderness is usually accompanied with small pods and seeds, and often with vining tips and a tendency to lodge. Unless there is lodging, such varieties are easily mown.

ABILITY TO RETAIN LEAVES.

Nearly all soy beans begin to shed their leaves as the pods ripen. There are a number of exceptions to this, like the Wisconsin Black, where the leaves remain green even after all the pods are mature. It may be possible to combine this character as a valuable feature to later varieties to be grown both for hay and grain.

COLOR OF THE SEED.

Yellow or green seeds are preferable to darker colors, as the shattered seeds are more easily found by hogs pasturing the field or stubble.

SHATTERING.

When grown for grain alone, shattering is a serious fault. Some varieties, like Guelph, shatter inordinately; others, like Peking, scarcely at all; while most varieties shatter somewhat, especially during changeable weather, if not harvested when ripe. As a rule the varieties with large pods and seeds shatter much worse than those with small pods and seeds. In a few varieties, like Brownie, the seed coats break badly in thrashing, a very objectionable character.

RESISTANCE TO DISEASE.

In sections where nematodes and cowpea wilt occur most soybean varieties are seriously affected by both these diseases. A few varieties, however, exhibit considerable resistance to these diseases, and there is good ground to believe that practically immune strains can be developed.

NONFILLING OF PODS.

In Louisiana and the southern half of Alabama, Mississippi, and Georgia late varieties of soy beans, especially the Mammoth, frequently fail to develop seeds, while earlier sorts are not thus affected. The cause for this has not been determined. At Biloxi, Miss., selections of No. 20797 fill their pods perfectly, so that there is little doubt that late varieties adapted to this section can be secured or developed.

SYNOPSIS OF THE GROUPS.

Plants bushy, the branches without tendency to twine, the terminals rarely elongated:
  Pods medium to large, crowded or scattered; stems coarse to medium . GROUP I
  Pods small, stem rather slender—
    Internodes short, the pods crowded; medium late................. II
    Internodes long, the pods scattered; very late; foliage dark green . III
Plants more or less twining, especially the long, slender terminals:
  Plants erect or suberect, slender, the internodes long; pods medium to small.. IV
  Plants procumbent, rather coarse; pods small; very late................ V

These groups merge into each other more or less, but in a general way represent fairly distinct types. The type of branching is the same in all, the differences being due to the relative development of the main stem and the lateral branches.

SYNOPSIS OF THE VARIETIES.

GROUP I.—190 VARIETIES.

Group I contains far more than half of the varieties of soy beans, including all the best known ones, such as Mammoth, Hollybrook, Guelph, and Ito San.

Seeds straw-yellow; germ yellow—71 varieties.—Nos. 14953, 14953 A, 14953 B, 16790 D, 17257 E, 17262 B, 17268, 17268 A, 17269, 17269 D, 17270, 17271, 17273, 17275, 17275 L, 17276, 17277, 17277 A, 17278, 17280, 17862 G, 18619, 19184 A, 19184 G, 19981, 19981 A, 19984, 20011 A, 20406, 20406 C, 20407 B, 20892, 20892 A, 20893 A, 21079 H, 21080 K, 21754, 21825, 22312, 22318, 22318 A, 22335, 22379, 22406, 22498, 22503, 22504 A, 22505, 22506, 22714, 22876, 22879, 22880, 22880 A, 22880 C, 22901, 22921 B, 22922, 22922 A, 23207 B, 23209, 23292, 23296, 23303, 24181, 24672, 24672 B, 24695, 24840, 25131, 27500.

Seeds olive-yellow; germ yellow—45 varieties.—Nos. 17251 A, 17253 C, 17254 C, 17262, 17263, 17263 D, 17264, 17267, 17268 C, 17271 E, 17275 B, 17862 E, 19184 D, 19184 E, 19186, 19981 B, 19984 D, 19985, 19985 F, 19985 K, 19986, 20011, 20405, 20405 C, 20406 E, 20798 C, 21079, 21079 D, 22381, 22381 B, 22504, 22507, 22537, 22644, 22644 B, 22644 C, 22645, 22646, 22874, 22898 A, 22920, 23207, 24183, 24839, 27501.

Seeds chromium green; germ green—17 varieties.—Nos. 17260, 17261, 17271 L, 17852 N, 17862 B, 18258 E, 20854, 21080, 21080 N, 22500, 22880 B, 22897, 23209 A, 23292 C, 23296 A, 23303 A, 25437 A.

Seeds brown to olive; germ yellow—28 varieties.—Nos. 17254 B, 17256, 17257, 17257 D, 17257 G, 17258, 17258 A, 17260 B, 17263 C, 17277 C, 17277 D, 18258 N, 19186 C, 19984 A, 19984 B, 20405 B, 20406 G, 20412 A, 20412 B, 21080 L, 21755, 22333, 22411 A, 22644 A, 23229, 24610, 25130, 25437 C.

Seeds black; germ yellow—18 varieties.—Nos. 17251, 17252, 17252 C, 17253, 17254, 17262 D, 17271 D, 20410, 22634, 23205, 23292 A, 23296 C, 23325, 23523, 23546, 24180, 24682, 25468.

Seeds black; germ green—7 varieties.—Nos. 14952, 17255, 19184, 21079 A, 22336 A, 23306, 25437 B.

Seeds bicolored; germ yellow—4 varieties.—Nos. 20407, 20411, 23213 A, 23311 B.

GROUP II.—4 VARIETIES.

Group II consists of four varieties which appear very promising as grain producers. The small size of the seeds is not objectionable, but on the contrary advantageous when grown for grain alone.

Seeds olive-yellow; germ yellow—2 varieties.—Nos. 17852 E, 23312.

Seeds black; germ yellow—2 varieties.—Nos. 17852 B, 23311 A.

GROUP III.—3 VARIETIES.

The four or five varieties belonging to Group III have a very different appearance from other soy beans. They all come from the valley of the Yangtse, and are said to be grown on the low-lying rice fields either as a green manure or for fodder. Their marked leafiness, large size, and slender stems make them especially desirable for hay. They are too late to mature at Washington.

Seeds brown to olive; germ yellow—3 varieties.—Nos. 9344, 20798, 23336.

Seeds black; germ yellow—3 varieties.—Nos. 6560, 20797, 23337.

Seeds bicolored; germ yellow—2 varieties.—Nos. 6559, 23338.

GROUP IV.—76 VARIETIES.

Group IV is the second largest group and includes the most important Manchurian varieties. From the standpoint of seed production, they promise to be superior to Group I because of their relatively slender stems, permitting easy mowing, and their smaller pods and seeds, which shatter less easily. They can also be planted more closely because they are less bushy.

Seeds straw-yellow; germ yellow—25 varieties.—Nos. 14954, 16789, 16789 A, 16789 B, 17272, 17277 E, 17862, 17862 C, 17862 F, 18258, 18258 A, 19186 F, 22534, 22921, 22921 A, 23208, 23213, 23297 B, 24184, 25133, 25134, 25134 A, 25437, 25438 B, 27499.

Seeds olive-yellow; germ yellow—8 varieties.—Nos. 17857 B, 19183 B, 19184 C, 20798 E, 21999 C, 21999 D, 22633, 22920 A.

Seeds chromium green; germ green—7 varieties.—Nos. 17857, 18258 D, 23311, 25135, 25438, 25438 A, 27498.

Seeds brown to olive; germ yellow—12 varieties.—Nos. 17852 C, 19186 D, 20409, 20412, 21999 B, 23211, 23232, 23292 B, 23297 A, 23299, 24672 A, 25136.

Seeds black; germ yellow—16 varieties.—Nos. 16790, 16790 B, 17852 D, 17852 R, 17861, 18227, 18259, 19183, 19186 B, 22538, 22899, 22899 A, 22919, 23291, 23297, 23338 B.

Seeds black; germ green—5 varieties.—Nos. 22380, 22407, 22501, 22900, 22927.

Seeds bicolored; germ yellow—3 varieties.—Nos. 17852, 21999, 23299.

GROUP V.—7 VARIETIES.

The varieties included in Group V are mostly from India, but the wild soy bean of China and Japan is also included. All form tangled masses of vines, difficult to mow, but perhaps of use as green manure and pasture crops.

Seeds straw-yellow; germ yellow—1 variety.—No. 24674.

Seeds brown to olive; germ yellow—1 variety.—No. 24673.

Seeds shining black; germ yellow—3 varieties.—Nos. 24642, 24675, 25137.

Seeds dull black, very small; germ yellow—1 variety.—No. 22428.

Seeds bicolored; germ yellow—1 variety.—No. 25118.

CATALOGUE OF SOY-BEAN VARIETIES.

The following is a complete list of soy beans imported by the United States Department of Agriculture, arranged chronologically in accordance with the serial numbers (S. P. I. numbers) assigned to them by the Office of Foreign Seed and Plant Introduction:

480. From South Usuri, Siberia, 1898. Seeds yellow. Insufficient varietal notes.
647. From Tokyo, Japan, 1898. Insufficient varietal notes.
648. From Tokyo, Japan, 1898. Insufficient varietal notes.
649. From Tokyo, Japan, 1898. Insufficient varietal notes.
650. From Tokyo, Japan, 1898. Insufficient varietal notes.
651. From Tokyo, Japan, 1898. Insufficient varietal notes.
652. From Tokyo, Japan, 1898. Insufficient varietal notes.
653. From Tokyo, Japan, 1898. Insufficient varietal notes.
654. From Tokyo, Japan, 1898. Insufficient varietal notes.
655. From Tokyo, Japan, 1898. Insufficient varietal notes.
656. From Tokyo, Japan, 1898. Insufficient varietal notes.
1492. From France, 1898. Seed brown. Insufficient varietal notes.
1493. From France, 1898. Seed black. Insufficient varietal notes.
2156. From France, 1898. "Yellow Etampes." See 17268.
2869. From Wuchang, Hupeh, China, 1899. Seeds yellow. Insufficient varietal notes.
2870. From Wuchang, Hupeh, China, 1899. Seeds green. Insufficient varietal notes.
2871. From Wuchang, Hupeh, China, 1899. Seeds green. Insufficient varietal notes.
2872. From Wuchang, Hupeh, China, 1899. Seeds green. Insufficient varietal notes.

3869. From China, 1899. Insufficient varietal notes.

3870. From China, 1899. See 17272.

3884. From Honolulu, 1899. Seeds yellow. Insufficient varietal notes.

3885. From Honolulu, 1899. Seeds black. Insufficient varietal notes.

3886. From Honolulu, 1899. Seeds green. Insufficient varietal notes.

4285. From Richmond, Va., 1900. "Mammoth." See 17280.

4628. From Amherst, Mass., 1900. "Medium Green." See 17261.

4912. From Japan. See 17270.

4913. From Japan. See 12400.

4914. From Japan. See 17266.

4980. From Yokohama, Japan. Insufficient varietal notes.

5039. From Paris, France. See 25468.

5517. From Macassar, Celebes. Insufficient varietal notes.

5764. Grown from 4912. See 17270.

5765. Grown from 4913. See 12400.

5766. Grown from 4914. See 17266.

6312. From Tokyo, Japan, 1901. See 17252.

6314. From Tokyo, Japan, 1901. See 17262.

6326. From Tokyo, Japan, 1901. See 17268.

6333. From Tokyo, Japan, 1901. See 17277.

6334. From Tokyo, Japan, 1901. See 9412.

6335. From Tokyo, Japan, 1901. See 17267.

6336. From Tokyo, Japan, 1901. See 9413.

6379. Grown from 3870. See 17272.

6386. From Pingyang, Korea, 1901. See 17254.

6396. From Pingyang, Korea, 1901. See 17271.

6397. From Pingyang, Korea, 1901. See 17263.

6414. From Pingyang, Korea, 1901. See 17256 and 22333.

6416. From Pingyang, Korea, 1901. See 17253.

6556. From central China. See 17269.

6558. From Hankow, Hupeh, China. See 17261.

6559. *Hankow.* From near Hankow, Hupeh, China, 1901. Plants slender, erect, very leafy; height 36 to 42 inches; very late; pubescence tawny; flowers purple; pods scattered; seeds brown, more or less banded with black, medium small, oblong, flattened; hilum brown; germ yellow. This variety is almost identical with the following, except for the color of the seed.

6560. *Riceland.* From near Hankow, Hupeh, China. Plants slender, erect, very leafy; height 36 to 60 inches; very late; pubescence tawny; flowers purple; pods scattered; seeds black, oblong, small, flattened; hilum pale; germ yellow. This is very similar to 20797, but has smaller seeds. The stock has been lost.

6561. From near Hankow, Hupeh, China. Seeds small, black, short, oblong; medium small; hilum pale; germ yellow. Apparently it was never grown.

8422. From Yokohama, Japan. See 17274.

8423. From Yokohama, Japan. See 17265.

8424. From Yokohama, Japan. See 17264.

8489. Grown from 6314. See 17262.

8490. Grown from 6333. See 17277.

8491. Grown from 6334. See 9412.

8492. Grown from 6386. See 17254.

8493. Grown from 6396. See 17271.

8494. Grown from 6336. See 9413.

8495. Grown from 6397. See 17263.

8496. Grown from 6416. See 17253.

8497. Grown from 6312. See 17252.

8584. From Chin-kiang, Kiangsu, China. Insufficient varietal notes.

8586. From Chin-kiang, Kiangsu, China. Insufficient varietal notes.

8900. From Anjo, Japan. Insufficient varietal notes.

9344. From Chin-hua, Kiangsu, China. The seed of this did not germinate. It is almost certainly the same as No. 23336.

9407. Grown from 4912. See 17270.

9408. Grown from 4913. See 12400.

9409. Grown from 4914. See 17266.

9410. Grown from 6312. See 17252.

9411. Grown from 6333. See 17277.

9412. Grown from 6334. According to Ball, indistinguishable from several other lots, all of which were united as 17251, which see.

9413. Grown from 6336. According to Ball, identical with 12400, the two being united as No. 17275, which see.

9414. Grown from 6386. See 17254.

9415. Grown from 6396. See 17271.

9416. Grown from 6397. See 17263.

9417. Grown from 6414. See 17256.

9417 A. Grown from 6414. See 22333.

9418. Grown from 6416. See 17253.

11179. Origin lost. Same as 17251.

11180. Origin lost. Insufficient varietal notes.

12399. Grown from 9407. See 17270.

12400. Grown from 9408. According to Ball, this proved identical with 9413, the seed of these two numbers being united as No. 17275, which see.

13502. *Ogemaw.* From West Branch, Mich. See 17258.

13503. *Guelph.* Grown at Arlington Experimental Farm from seed from Thorburn & Co. See 17261.

14952. *Shanghai.* From Shanghai, China, 1905. Erect, stout, bushy; height 30 to 36 inches; late; pubescence tawny; flowers both purple and white; pods large, 2¼ to 2½ inches long, tumid, scattered, shattering little; seeds black, large, 8 to 8½ mm. long, elliptical; hilum pale; germ green. Grown five seasons. No. 22311, also from Shanghai, proved to be the same.

14953. *Edward.* From Shanghai, China, 1905. Plants stout, erect, bushy; height 36 to 42 inches; very late; pubescence gray; flowers purple; pods large, 2 to 2½ inches, compressed, scattered, shattering little; seeds straw-yellow, large, 8 to 9 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown five seasons.

14953 A. A field selection in 1907. Plants stout, erect, bushy; height 30 to 36 inches; late; pubescence tawny; flowers purple; pods large, 2 to 2½ inches long, compressed, half crowded, shattering little; seeds straw-yellow, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown two seasons.

14953 B. A field selection in 1907. Plants stout, erect, bushy; height 30 to 40 inches; very late; pubescence gray; flowers purple; pods large, 2¼ to 2½ inches long, tumid, scattered, shattering little; seeds straw-yellow, large, 8 to 8½ mm. long, elliptical, much flattened; hilum seal-brown; germ yellow. Grown two seasons.

14954. *Acme.* From Shanghai, China, 1905. Plants slender, erect, the tips twining; height 36 to 42 inches; late; pubescence gray (50 per cent) and tawny (50 per cent); flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds straw-yellow, small, 6½ to 7 mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown five seasons.

15887. From Chekiang Province, China. Indistinguishable from Riceland, 20797. Grown in 1907.

16789. *Brooks.* From Hangchow, Chekiang, China, 1905. Plants slender, erect, the tips twining; height 36 to 42 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum light to dark brown; germ yellow. Grown four seasons. This is said to be the bean-cake bean grown so extensively in the Manchurian provinces and is a most valuable crop.

16789 A. *Flava.* A field mass selection in 1907. Plants slender, erect, the tips twining; height 28 to 34 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

16789 B. A field mass selection in 1907. Plants slender, erect, the tips twining; height 36 to 42 inches; late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, tumid, scattered, shattering little; seeds straw-yellow, medium large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum light; germ yellow. Grown two seasons.

16790. *Cloud.* From Hangchow, Chekiang, China, 1905. Plants slender, erect, the tips twining; height 34 to 40 inches; medium late; pubescence both gray and tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds black, medium small, 7 to 7½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown four seasons. This variety is said to be an excellent table bean. No. 22535, from Weihsien, China, is the same thing.

16790 B. A field mass selection in 1907. Plants erect, the tips twining; height 48 to 52 inches; medium late; pubescence gray (10 per cent) and tawny (90 per cent); flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds dull black, medium-sized, 8 to 8½ mm. long, oblong, much flattened; hilum seal-brown; germ yellow. Grown two seasons.

16790 D. A pure field selection in 1907. Plants erect, stout, bushy; height 20 to 24 inches; medium late; pubescence gray; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, crowded, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17251. *Buckshot.* Plants stout, erect, bushy; height 14 to 18 inches; early; pubescence tawny; flowers white; pods medium to large, 1½ to 2 inches long, crowded, shattering little; seeds black, large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown eight seasons. Buckshot has been on the market for a number of years and sold as Black, Early Black, Medium Early Black, Extra Early Black, Large Black, etc. No. 17251 is composed of the progeny of 6334 combined with various other lots. See page 29. Nos. 19987 and 22883 from Japan are very closely similar, if not identical.

17251 A. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence tawny; flowers purple; pods large, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds olive-yellow, medium large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum black; germ yellow. Grown two seasons.

17252. *Flat King.* The progeny of 6312 from Tokyo, Japan, 1901. Plants stout, erect, bushy; height 24 to 30 inches; late; pubescence tawny; flowers white; pods large, 2¼ to 2½ inches long, compressed, half crowded, shattering little; seeds black, large, 11 to 11½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown nine seasons. This variety was also obtained from Yokohama, Japan, No. 19982, and again from Tokyo, No. 22875.

17252 C. A field mass selection in 1907. Plants stout, erect, bushy; height 30 to 36 inches; late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds black, medium small, 6 to 6½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17253. *Nuttall.* The progeny of 6416 from Pingyang, Korea, 1901. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence tawny; flowers white; pods medium large, 1¾ to 2¼ inches long, crowded, shattering little; seeds black, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown nine seasons. No. 22334 is undoubtedly the progeny of 17253 as shown by records.

17253 C. A field mass selection in 1907. Plants stout, erect, bushy; height 12 to 16 inches; medium late; pubescence tawny; flowers both purple and white; pods medium large, 2 to 2⅛ inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, oval; hilum black; germ yellow. Grown two seasons.

17254. *Ebony.* The progeny of 6386 from Pingyang, Korea, 1901. Plants stout, erect, bushy; height 22 to 26 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, half crowded, shattering moderately; seeds black, medium small, 7 to 7½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown nine seasons. This variety was also received from Swatow, China, 1908 (S. P. I. No. 22886). Ebony has proved a valuable variety in southern Illinois and especially through the work of Mr. Ralph Allen, of Delavan, Ill., has become well known as No. 9414 and also as "Black Beauty."

17254 B. A pure field selection in 1907. Plants stout, erect, bushy; height 32 to 36 inches; medium late; pubescence gray; flowers purple; pods medium-sized, 1¼ to 1½ inches long, tumid, half crowded, shattering little; seeds cinnamon brown, small, 5½ to 6 mm. long, subglobose; hilum pale; germ yellow. Grown two seasons.

17254 C. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 26 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering moderately; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum clove-brown; germ yellow. Grown two seasons.

17255. *Kingston.* "Japanese Number 15" from Rhode Island Agricultural Experiment Station, originally from Japan. Plants stout, bushy, erect; height 16 to 22 inches; medium late; pubescence tawny; flowers white; pods small, 1¼ to 1½ inches long, tumid, crowded, shattering little; seeds black, small, 5½ to 6 mm. long, subglobose; hilum pale; germ green. Grown nine seasons. See also page 31.

17256. *Brownie.* The progeny of 6414 from Pingyang, Korea, 1901. Plants stout, erect, bushy; height 20 to 30 inches; medium late; pubescence gray; flowers purple; pods small, 1⅛ to 1½ inches long, tumid, crowded, shattering little; seeds cinnamon brown, small, 5 to 5½ mm. long, subglobose; hilum pale; germ yellow. Grown nine seasons.

17256 A. *Baird.* See 22333.

17257. *Eda.* From Rhode Island Agricultural Experiment Station, 1903, but originally introduced by the Kansas Agricultural Experiment Station in 1890 as *Yamagata Cha-daidzu.* Plants stout, erect, bushy; height 14 to 20 inches; medium; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering moderately; seeds deep brown, large, 8½ to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown nine seasons. See also page 31.

17257 D. A field mass selection in 1907. Plants stout, erect, bushy; height 20 to 26 inches; medium; pubescence tawny; flowers both purple and white; pods medium small, 1¼ to 1½ inches long, tumid, half crowded, shattering moderately; seeds seal-brown, medium-sized, 6½ to 7 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17257 E. A field mass selection in 1907. Plants stout, erect, bushy; height 18 to 22 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum dark brown; germ yellow. Grown two seasons.

17257 G. A field mass selection in 1907. Plants stout, erect, bushy; height 20 to 26 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds buff, medium-sized, 6 to 6½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17258. *Ogemaw.* The progeny of 13502 from E. E. Evans, West Branch, Mich., 1904. Plants stout, erect, bushy; height 18 to 22 inches; medium; pubescence tawny; flowers white; pods large, 2 to 2¼ inches long, tumid, crowded, shattering badly; seeds deep brown, large, 8½ to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Compare also page 31 and see notes under Nos. 21755 and 25212.

17258 A. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium early; pubescence gray; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds buff-brown, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17260. *Samarow.* From J. M. Thorburn & Co., 1902. Plants stout, erect, bushy; height 15 to 18 inches; medium; pubescence gray; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds chromium green, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum brown; germ green. Grown nine seasons. This variety has not occurred in any of our Asiatic importations. It is advertised under the same name by German and Italian seedsmen, and such an importation, No. 22411, from Italy, proved identical with 17260. See also page 31

17260 B. A pure field selection in 1907. Plants stout, erect, bushy; height 14 to 18 inches; medium; pubescence gray; flowers purple; pods medium large, 2⅛ to 2¼ inches long, compressed, crowded, shattering moderately; seeds clove brown to almost black, medium-sized, 9 to 9½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

17261. *Guelph.* From J. M. Thorburn & Co., 1902. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering much; seeds chromium green, medium to medium large, 7 to 8 mm. long, elliptical, slightly flattened; hilum brown; germ green. Grown eight seasons. This variety is advertised by a German seedsman, and such an importation, No. 22320, proved identical with 17261. According to Ball, No 6558 from Hankow, China, is the same as Guelph. Compare page 30.

17262. *Yosho.* The progeny of 6314 from Tokyo, Japan, 1901. Plants stout, erect, bushy; height 22 to 26 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds olive-yellow, large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum black; germ yellow. Grown nine seasons.

17262 B. A pure field selection in 1907. Plants stout, erect, bushy; height 10 to 14 inches; medium early; pubescence tawny; flowers white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

17262 D. A field mass selection in 1907. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering moderately; seeds black, medium large, 8 to 8½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

17263. *Austin.* The progeny of 6397 from Pingyang, Korea, 1901. Plants stout, erect, bushy; height 32 to 36 inches; late; pubescence gray; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds olive-yellow, medium large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown nine seasons. This variety was also distributed under Agrostology No. 1539.

17263 C. A field mass selection in 1907. Plants stout, erect, bushy; height 30 to 34 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds buff, medium small, 6½ to 7 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17264. *Tokyo.* The progeny of 8424 from Tokyo, Japan, 1901. Plants stout, erect, bushy; height 30 to 36 inches; late; pubescence gray; flowers both purple and white; pods medium large, 1½ to 2 inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown nine seasons. This variety was also obtained from Kobe, Japan, No. 20893.

17265. The progeny of 8423 from Yokohama, Japan, 1902. According to Ball this proved the same as the preceding and was united with it.

17266. The progeny of 4914 from Japan. According to Ball this also was the same as Tokyo 17264 and was finally united with it.

17267. *Hope.* The progeny of 6335 from Tokyo, Japan, 1901. Plants stout, erect, bushy; height 28 to 34 inches; late; pubescence gray; flowers both purple and white; pods medium large, 1¾ to 2¼ inches long, tumid, half crowded, shattering little; seeds olive-yellow, large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown nine seasons. No. 22881, also from Tokyo, is the same variety.

17268. *Ito San.* Plants stout, erect, bushy; height 18 to 22 inches; medium in maturity; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale, a brown speck at the micropylar end; germ yellow. Grown nine seasons.

This variety has also been known as "Japan Pea," "Coffee Berry," "Early Yellow," "Early White," and "Yellow Eda Mame." It is one of the earliest importations, very probably 1850, as the "Japan Pea." The Kansas Agricultural Experiment Station obtained this variety from Japan in 1890. Only one European importation has been made, this being from Vilmorin-Andrieux & Co., No. 21818, who advertise the variety as "Yellow Etampes." See also page 28.

17268 A. A field mass selection in 1907. Plants stout, erect, bushy; height 18 to 24 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, crowded, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

17268 C. A field mass selection in 1907. Plants stout, erect, bushy; height 20 to 26 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds olive-yellow, medium-sized, 6½ to 7 mm. long, elliptical, much flattened; hilum seal-brown; germ yellow. Grown two seasons.

17269. *Medium Yellow.* The progeny of 6556 from central China, 1901. Plants stout, erect, bushy; height 30 to 36 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown nine seasons. This is the variety grown as Medium Yellow by the Tennessee Agricultural Experiment Station.

17269 D. A field mass selection in 1907. Plants stout, erect, bushy; height 24 to 30 inches; late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, crowded, shattering little; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

17270 The progeny of 4912 from Japan in 1900. Other numbers of the same progeny are 12399, 9407, and 5764. Plants stout, erect, bushy; height 24 to 30 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum light to seal brown; germ yellow. Grown nine seasons.

17271. *Haberlandt.* The progeny of 6396 from Pingyang, Korea, 1901. Plants stout, erect, bushy; height 24 to 30 inches; medium late; pubescence tawny; flowers both purple and white; pods crowded, medium-sized, 1¾ to 2 inches long, tumid, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown nine seasons.

17271 D. A pure field selection in 1907. Plants stout, erect, bushy; height 18 to 24 inches; medium late; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds black, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

17271 L. A pure field selection in 1908. Plants stout, erect, bushy; height 16 to 20 inches; medium early; pubescence tawny; flowers white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds chromium green, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum black; germ green. Grown one season.

17272. The progeny of 3870 from China in 1899. Plants slender, erect, the tips twining; height 32 to 36 inches; medium late; pubescence gray; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 6½ to 7 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown ten seasons. Ball included this variety in Hollybrook, but it is different.

17273. *Butterball.* From the Rhode Island Agricultural Experiment Station, 1903, originally from Japan. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence gray; flowers white; pods medium-sized, 1½ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown seven seasons. This variety has also been obtained from the following foreign sources: Dammann & Co., Naples, Italy, No. 22415; Tokyo, Japan, Nos. 22878 and 22884; and Yokohama, Japan, No. 8422. See also page 30.

17274. The progeny of 8422 from Yokohama, Japan. Identical with 17273.

17275. *Amherst.* The united progenies of 4913 from Japan, 1900, and 6336 from Tokyo, Japan, 1901. Plants stout, erect, bushy; height 24 to 28 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1 to 1½ inches long, tumid, crowded, shattering moderately; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum dark brown; germ yellow. Grown nine seasons.

17275 B. A field mass selection in 1907. Plants stout, erect, bushy; height, 14 to 18 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering much; seeds olive-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

17275 L. A field mass selection in 1908. Plants stout, erect, bushy; height, 14 to 18 inches; medium early; pubescence gray; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, crowded, shattering moderately; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown one season.

17276. The progeny of Agrostology No. 1299 from Havre, France. Plants stout, erect, bushy; height, 14 to 18 inches; early; pubescence gray; flowers white; pods medium-sized, 1½ to 2 inches long, tumid, half crowded and shattering little; seeds straw-yellow, medium small, 7 to 7½ mm. long, elliptical, much flattened; hilum light to seal-brown; germ yellow. Grown eight seasons.

17277. *Manhattan.* The progeny of 6333 from Tokyo, Japan. Plants stout, erect, bushy; height, 14 to 18 inches; medium early; pubescence gray; flowers white; pods medium large, 1¾ to 2 inches long, tumid, crowded, shattering little; seeds straw-yellow, medium large, 8 to 8½ mm. long, elliptical, much flattened; hilum light brown; germ yellow. Grown ten seasons.

17277 A. A pure field selection in 1907. Plants stout, erect, bushy; height, 22 to 26 inches; medium late; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, compressed, crowded, shattering little; seeds straw-yellow, medium large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown two seasons.

17277 C. A pure field selection in 1907. Plants stout, erect, bushy; height 16 to 20 inches; early; pubescence tawny; flowers purple; pods, large, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds raw umber, large, 8½ to 9 mm. long, elliptical, much flattened, hilum pale; germ yellow. Grown two seasons.

17277 D. A pure field selection in 1907. Plants stout, erect, bushy; height 14 to 20 inches; medium; pubescence gray; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, half crowded, shattering little; seeds cinnamon brown, medium-sized, 8½ to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

17277 E. A pure field selection in 1907. Plants slender, erect, the tips vining; height 24 to 28 inches; medium; pubescence gray; flowers white; pods medium small, 1¼ to 1½ inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium small, 6 to 6½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

17278. *Hollybrook.* From Arkansas Agricultural Experiment Station, 1904. Plants stout, erect, bushy; height 24 to 30 inches; late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, crowded, shattering little; seeds straw-yellow, small to medium, 5½ to 6½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown six seasons. This variety was introduced by Messrs. T. W. Wood & Sons, of Richmond, Va., originally found mixed in Mammoth. Nos. 17269, 17270, 17272, and 17276 are all distinct.

17280. *Mammoth.* A combination of various lots; all from American sources. Plants stout, erect, bushy; height 36 to 42 inches; late; pubescence gray; flowers white; pods medium-sized, 1½ to 1¾ inches long, scattered, shattering little; seeds straw-yellow, medium small, 6½ to 7 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown ten seasons. This variety has also been grown under Nos. 4285, 25093, and 25162. It is the standard commercial late variety, more extensively grown at present than any other. See also page 29.

17520. *Hollybrook.* From Wood & Sons, Richmond, Va. Same as 17278.

17852. *Meyer.* From Peking, Chihli, China, 1906. Plants slender, erect, the tips twining; height 32 to 38 inches; late; pubescence tawny; flowers purple; pods large, 2 to 2¼ inches long, tumid, scattered, shattering little; seeds variable, black and brown, the colors usually in concentric bands, large, 8½ to 9 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown four seasons. The beans of this variety are said to be roasted and sold in Peking as delicatessen.

17852 B. *Peking.* A pure field selection in 1907. Plants slender, erect; height 32 to 36 inches; medium late; pubescence tawny; flowers white; pods small, 1¾ to 2 inches long, compressed, shattering little; seeds black, medium small, 7 to 7½ mm. long, oblong or nearly so, much flattened; hilum pale; germ yellow. Grown two seasons.

17852 C. A field mass selection in 1907. Plants slender, erect, the tips twining; height 24 to 30 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering moderately; seeds olive-brown, medium-sized, 8 to 8½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

17852 D. A pure field selection in 1907. Plants slender, suberect, the tips twining; stems 42 to 52 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds black, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

17852 E. A field mass selection in 1907. Plants slender, erect; height 24 to 30 inches; medium late; pubescence gray; flowers both purple and white; pods small, 1¼ to 1¾ inches long, tumid, shattering little; seeds olive-yellow, medium small, 6½ to 7 mm. long, elliptical, much flattened; hilum light brown; germ yellow. Grown two seasons.

17852 N. A field mass selection in 1907. Plants stout, erect, bushy; height 18 to 30 inches; medium late; pubescence tawny; flowers purple; pods large, 2 to 2¼ inches long, compressed, half crowded, shattering much; seeds chromium green, large, 9½ to 10½ mm. long, broadly elliptical, much flattened; hilum slate-black; germ green. Grown two seasons. Except for color of seed this is identical with 17252, Flat King.

17852 R. A field mass selection in 1907. Plants slender, suberect, the tips twining; stems 48 to 56 inches; medium late; pubescence gray (10 per cent) and tawny (90 per cent); flowers both purple and white; pods small, 1¼ to 1½ inches long, compressed, scattered, shattering moderately; seeds medium-sized, 6½ to 7 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

17857. From Shan-hai-kwan, Chihli, China, 1906. Plants slender, erect, the tips twining; height 28 to 32 inches; medium late; pubescence tawny; flowers both purple and white; pods medium large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds chromium green, medium-sized, 7 to 8 mm. long, elliptical, slightly flattened; hilum slate-black; germ green. Grown four seasons.

17857 B. A field mass selection in 1907. Plants slender, erect, the tips twining; height 30 to 36 inches; late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2⅛ inches long, compressed, scattered, shattering moderately; seeds olive-yellow, medium small, 8 to 8½ mm. long, elliptical, much flattened; hilum black; germ yellow. Grown two seasons.

17861. *Jet.* From Sachon, Chihli, China, 1906. Plants slender, erect, the tips twining; height 36 to 48 inches; medium late; pubescence gray (40 per cent) and tawny (60 per cent); flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering moderately; seeds black, medium small, 7 to 7½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown four seasons. A variety said to be grown for fodder and considered an excellent food for stock.

17862. *Sherwood.* From Tientsin, Chihli, China, 1906. Plants slender, erect, the tips twining; height 24 to 26 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale or light brown; germ yellow. Grown four seasons. This variety is said to be excellent for making bean cheese. No. 22898 from Paotingfu, Chihli, China, is the same thing.

17862 B. A pure field selection in 1907. Plants stout, erect, bushy; height 32 to 38 inches; medium late; pubescence gray; flowers purple; pods medium-sized, 1½ to 2 inches long, compressed, scattered, shattering little; seeds chromium green, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum black; germ green. Grown two seasons.

17862 C. A field mass selection in 1907. Plants slender, suberect, the tips twining; height 32 to 38 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 2 to 2¼ incheslong, tumid, scattered, shattering moderately; seeds straw-yellow, medium small, 7½ to 8 mm. long, elliptical, much flattened; hilum seal-brown; germ yellow. Grown two seasons.

17862 E. A field mass selection in 1907. Plants stout, erect, bushy; height 30 to 34 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches, tumid, half crowded, shattering little; seeds olive-yellow, medium sized, 7 to 7½ mm. long, elliptical, much flattened; hilum pale to light brown; germ yellow. Grown two seasons.

17862 F. A field mass selection in 1907. Plants slender, erect, the tips twining; height 24 to 26 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale or brown; germ yellow. Grown two seasons.

17862 G. A pure field selection in 1907. Plants stout, erect, bushy; height 30 to 36 inches; medium late; pubescence tawny; flowers purple; pods medium sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, much flattened; hilum pale to light brown; germ yellow. Grown two seasons.

18227. *Chernie.* From Khabarovsk, Siberia, 1906. Plants slender, erect, the tips twining; height 22 to 28 inches; medium early; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds black, medium-sized, 7½ to 8½ mm. long, oblong, much flattened; hilum pale; germ yellow; leaves persist when pods are ripening. Grown four seasons.

18258. From Pee-san, Chihli, China, 1906. Plants slender, erect, the tips twining; height 28 to 34 inches; medium late; pubescence both gray and tawny; flowers both purple and white; pods medium-sized, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum brown; germ yellow. Grown four seasons.

18258 A. A field mass selection in 1907. Plants slender, erect, the tips twining; height 30 to 36 inches; medium late; pubescence both gray and tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum seal-brown; germ yellow. Grown two seasons.

18258 D. A pure field selection in 1907. Plants slender, erect, the tips twining; height 30 to 34 inches; medium late; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering little; seeds chromium green, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum black; germ green. Grown two seasons.

18258 E. A field mass selection in 1907. Plants stout, erect, bushy; height 26 to 30 inches; medium late; pubescence both gray and tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds chromium green, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum black; germ green. Grown two seasons.

18258 N. A pure field selection in 1908. Plants stout, erect, bushy; height 28 to 32 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds olive, with black saddle, medium-sized, 7 to 7½ mm. long, oblong, much flattened; hilum black; germ yellow. Grown two seasons.

18259. *Pingsu.* From Tschang-ping-tsu, Chihli, China, 1906. Plants slender, erect, the tips twining; height 32 to 36 inches; medium late; pubescence gray (50 per cent) and tawny (50 per cent); flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering much; seeds black, small, 8 to 8½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown four seasons. This bean is said to be grown in the northern country as a nitrogen-supplying crop with sorghum, corn, or millet.

18459. Guelph. From West Branch, Mich., 1906. Same as No. 17261.

18460. Buckshot. From West Branch, Mich., 1906. Same as No. 17251.

18619. From Shanghai, Kiangsu, China, 1906. Plants stout, erect, bushy; height 24 to 30 inches; very late; pubescence tawny; flowers purple, pods medium-sized, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum dark brown; germ yellow. Grown four seasons. This variety is said to be used in Shanghai as a vegetable after the beans have made sprouts several inches long.

19183. *Wilson.* From Newchwang, Manchuria, 1906. Plants slender, erect, the tips twining; height 36 to 48 inches; medium late; pubescence gray (10 per cent) and tawny (90 per cent); flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds black, medium, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown three seasons. This variety has an admixture of medium-sized, subglobose, black seed with green cotyledons. This variety is said to be grown for oil, the exhausted material being exported as a very valuable fertilizer.

19183 B. A field mass selection in 1907. Plants slender, erect, the tips twining; height 36 to 48 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds olive-yellow, medium small, 7 to 7½ mm. long, elliptical, much flattened; hilum light brown to russet; germ yellow. Grown two seasons.

19184. *Fairchild.* From Newchwang, Manchuria, 1906. Plants stout, erect, bushy; height, 30 to 34 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds black, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown three seasons. This is said to be a very rare variety used both for food and for making a superior oil.

19184 A. A pure field selection in 1907. Plants stout, erect, bushy; height 34 to 38 inches; medium late; pubescence gray; flowers white; pods medium-sized, small, 1⅛ to 1¾ inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

19184 C. A field mass selection in 1907. Plants slender, erect, the tips twining; height 36 to 48 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, tumid, scattered, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum black; germ yellow. Grown two seasons.

19184 D A field mass selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium late; pubescence tawny; flowers both purple and white; pods large, 2 to 2¼ inches long, tumid, half crowded, shattering little; seeds olive-yellow, large, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

19184 E. A pure field selection in 1907. Plants stout, erect, bushy; height 22 to 26 inches; medium late; pubescence gray; flowers white; pods medium-sized, 1¾ to 2¼ inches long, tumid, half crowded, shattering little; seeds olive-yellow, medium large, 7½ to 8 mm. long, oval; hilum brown; germ yellow. Grown three seasons.

19184 G. A pure field selection in 1907. Plants stout, erect, bushy; height 18 to 24 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, crowded, shattering moderately; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum black; germ yellow. Grown two seasons.

19186. *Morse.* From Newchwang, Manchuria, 1906. Plants stout, erect, bushy; height 30 to 36 inches; medium late; pubescence gray; flowers both purple and white; pods medium large, 1¾ to 2¼ inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown three seasons. This variety is said to be the most common one from which oil is extracted at Newchwang.

19186 B. A pure field selection in 1907. Plants slender, suberect, the tips twining; stems 48 to 60 inches; medium late; pubescence gray; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds black, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

19186 C. A field mass selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium late; pubescence gray; flowers both purple and white; pods large, 2 to 2½ inches long, tumid, half crowded, shattering little; seeds cinnamon brown, medium large, 7½ to 8 mm. long, elliptical, slightly flattened, breaking easily; hilum pale; germ yellow. Grown two seasons.

19186 D. A pure field selection in 1907. Plants slender, suberect, the tips twining; stems 48 to 56 inches long; medium late; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds brown, medium-sized, 8½ to 9 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

19186 F. A field mass selection in 1907. Plants slender, suberect, the tips twining; height 36 to 42 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum dark brown; germ yellow. Grown two seasons.

19951 *Mammoth.* From Richmond, Va.

19981. From Yokohama, Japan, 1907. Plants stout, erect, bushy; height 18 to 22 inches; medium; pubescence gray; flowers both purple and white; pods large, 2¼ to 2½ inches long, tumid, crowded, shattering moderately; seeds straw-yellow, large, 9½ to 10 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown three seasons. No. 19983 from Yokohama is the same, and the variety has also been obtained from Tokyo, Japan, Nos. 22882 and 22885.

19981 A. A field mass selection in 1907. Plants stout, erect, bushy; height 22 to 26 inches; late; pubescence gray; flowers both purple and white; pods large, 2¼ to 2½ inches long, compressed, crowded, shattering little; seeds straw-yellow, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

19981 B. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence tawny; flowers purple; pods large, 2 to 2¼ inches long, tumid, crowded, shattering little; seeds olive-yellow, large, 7½ to 8 mm. long, oval; hilum black; germ yellow. Grown two seasons.

19982. From Yokohama, Japan, 1907. This is identical with Flat King, 17252.

19983. From Yokohama, Japan, 1907. This is the same variety as 19981.

19984. *Natsu.* From Yokohama, Japan, 1907. Plants stout, erect, bushy; height 18 to 30 inches; late; pubescence gray (25 per cent) and tawny (75 per cent); flowers both purple and white; pods medium large, 2 to 2¼ inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown three seasons.

19984 A. A pure field selection in 1907. Plants stout, erect, bushy; height 30 to 42 inches; medium late; pubescence tawny; flowers purple; pods medium small, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds brownish olive, medium-sized, 6 to 6½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

19984 B. A pure field selection in 1907. Plants stout, erect, bushy; height 24 to 30 inches; late; pubescence gray; flowers white; pods medium large, 2 to 2¼ inches long, tumid, half crowded, shattering little; seeds buff, medium large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

19984 D. A field mass selection in 1907. Plants stout, erect, bushy; height 36 to 42 inches; late; pubescence tawny; flowers both purple and white; pods medium large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds olive-yellow, medium-sized, 8½ to 9 mm. long, elliptical, much flattened; hilum clove-brown; germ yellow. Grown two seasons.

19985. *Nemo.* From Yokohama, Japan, 1907. Plants stout, erect, bushy; height 28 to 32 inches; medium late; pubescence tawny; flowers white; pods medium-sized 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum light to slate-black; germ yellow. Grown three seasons.

19985 F. A field mass selection in 1907. Plants stout, bushy; height 32 to 38 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering little; seeds olive-yellow, medium-sized, 6½ to 7 mm. long, elliptical, slightly flattened; hilum black; germ yellow. Grown three seasons.

19985 K. A field mass selection in 1908. Plants stout, erect, bushy; height 24 to 30 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 2 inches, tumid, half crowded, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown one season.

19986. *Okute.* From Yokohama, Japan, 1907. Plants stout, erect, bushy; height 14 to 18 inches; early; pubescence tawny; flowers both purple and white; pods large, 2 to 2¼ inches long, tumid, half crowded, shattering little; seeds olive-yellow, large, 9½ to 10 mm. long, elliptical, much flattened; hilum slate-colored; germ yellow. Grown three seasons. This variety was also received from Tokyo, Japan, No. 22877.

19987. From Yokohama, Japan. Very similar to, if not identical with Buckshot, 17251.

20011. From Ko-bau, northern Korea, 1906. Plants stout, erect, bushy; height 15 to 18 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds olive-yellow, small to medium, 6½ to 7 mm. long, elliptical, much flattened; hilum seal-brown; germ yellow; leaves persisting when pods are ripening. Grown three seasons. This variety is said to be grown at high elevation in Korea.

20011 A. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds straw-yellow, small, 6½ to 7 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown two seasons.

20405. *Habaro.* From Khabarovsk, Siberia, 1906. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence both gray and tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown three seasons.

20405 B. *Chestnut.* A field mass selection in 1907. Plants stout, erect, bushy; height 24 to 30 inches; medium early; pubescence gray (25 per cent) and tawny (75 per cent); flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds brown, medium large, 7 to 7½ mm. long, oblong, much flattened; hilum pale; germ yellow; leaves persist when pods are ripening. Grown two seasons.

20405 C. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 26 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

20406. *Elton.* From Khabarovsk, Siberia, 1906. Plants stout, erect, bushy; height 28 to 32 inches; medium early; pubescence both gray and tawny; flowers purple; pods medium large, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium large, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown three seasons.

20406 C. A pure field selection in 1907. Plants stout, erect, bushy; height 18 to 22 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering little; seeds straw-yellow with brown saddle, medium-sized, 8 to 9 mm. long, elliptical, much flattened; hilum brown; germ yellow; leaves persisting while pods are ripening. Grown two seasons.

20406 E. A pure field selection in 1907. Plants stout, erect, bushy; height 12 to 16 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, crowded, shattering moderately; seeds olive-yellow, medium-sized, 8 to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

20406 G. A pure field selection in 1907. Plants stout, erect, bushy; height 24 to 28 inches; medium early; pubescence gray; flowers purple; pods large, 2 to 2¼ inches long, compressed, half crowded, shattering little; seeds light brown, large, 8½ to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

20407. *Brindle.* From Merkoechofka, Siberia, 1906. Plants stout, erect, bushy; height 16 to 20 inches; medium; pubescence tawny; flowers purple; pods large, 1¾ to 2¼ inches long, tumid, half crowded, shattering little; seeds brown and black, the colors somewhat concentrated in bands, large, 8 to 9 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown three seasons. This variety is said to be used in Siberia for human food, being boiled with millet.

20407 B. A field mass selection in 1907. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ mm. long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 8½ to 9 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown two seasons.

20408. From Khabarovsk, Siberia, 1906. Seeds black. They failed to germinate in 1907.

20409. *Hansen.* From Merkoechofka, Siberia, 1906. Plants slender, erect, the tips twining; height 16 to 20 inches; early; pubescence tawny; flowers purple; pods small, 1¼ to 1½ mm. long, tumid, crowded, shattering little; seeds brown, very small, 5 to 5½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown three seasons.

20410. From Merkoechofka, Siberia, 1906. Plants stout, erect, bushy; height 12 to 15 inches; medium early; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, compressed, half crowded, shattering much; seeds black, small, 6 to 6½ mm. long, elliptical, much flattened; hilum pale; germ yellow; leaves persist when pods are ripening. Grown three seasons.

20411. From Merkoechofka, Siberia, 1906. Plants stout, erect, bushy; height 16 to 20 inches; medium early; pubescence tawny; flowers both purple and white; pods small, 1¼ to 1½ inches long, tumid, crowded, shattering moderately; seeds dull black marbled with brown, small, 5 to 5½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown three seasons.

20412. *Merko.* From Merkoechofka, Siberia, 1906. Plants slender, erect, the tips twining; height 28 to 32 inches; medium early; pubescence gray (60 per cent) and tawny (40 per cent); flowers both purple and white; pods medium small, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds brown, small, 7½ to 8 mm. long, oblong, much flattened, hilum pale; germ yellow; leaves persist when pods are ripening. Grown three seasons.

20412 A. A pure field selection in 1907. Plants stout, erect, bushy; height 16 to 18 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds deep brown, medium small, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow; leaves persist when pods are ripening. Grown two seasons.

20412 B. A pure field selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds olive to mummy brown, medium large, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow; leaves persist when pods are ripening. Grown two seasons.

20414. From Merkoechofka, Siberia, 1906. Identical with Chernie, 18227.

20629. From Manchuria, March, 1907. Seeds failed to germinate.

20699. From Usuri Province, Siberia, March, 1907. Seeds failed to germinate.

20797. *Riceland.* From Chinhuafu, near Shanghai, Kiangsu, China, 1907. Plants slender, erect, very leafy; height 36 to 42 inches; very late; pubescence tawny; flowers purple; pods medium small, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds black, medium small, 6½ to 7 mm. long, oblong; much flattened; hilum pale; germ yellow. Grown three seasons. No. 23337 from Shanghai is the same thing. This variety is said to be grown as a second crop in low-lying rice fields and mainly used as a fodder for domestic animals. It is not quite identical with the original Riceland, No. 6560.

20798. *Barchet.* From Chinhuafu, Kiangsu, China, 1907. Plants slender, erect, very leafy; height 36 to 42 inches; late; pubescence tawny; flowers purple; pods medium small, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds dark olive-brown, medium-sized, 6½ to 7 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown three seasons. This variety has also been grown under No. 23336 from Shanghai, China, and 9344 is almost certainly the same thing.

20798 C. A selection out of the original seed of 20798. Plants stout, erect, bushy; height 30 to 36 inches; very late; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum burnt umber; germ yellow; leaves persist while pods are ripening. Grown two seasons.

20798 E. A selection out of the original seed of 20798. Plants slender, erect, the tips twining; height 36 to 42 inches; very late; pubescence tawny; flowers purple; pods medium-sized, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds olive-yellow, 6½ to 7 mm. long, elliptical, much flattened; hilum dark brown; germ yellow. Grown two seasons.

20854. *Tashing.* From Harbin, Manchuria, 1907. Plants stout, erect, bushy; height 14 to 18 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds chromium green, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum black; germ green. Grown three seasons.

20892. From Kobe, Japan, 1907. Plants stout, erect, bushy; height 24 to 30 inches; late; pubescence gray (5 per cent) and tawny (95 per cent), flowers both purple and white; pods large, 2 to 2¼ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown three seasons.

20892 A. A pure field selection in 1908. Plants stout, erect, bushy; height 12 to 18 inches; medium early; pubescence gray; flowers purple; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 8½ to 9 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

20893. From Kobe, Japan, 1907. This proved to be identical with Tokyo, 17264.

20893 A. A pure field selection in 1908. Plants stout, erect, bushy; height 24 to 30 inches; late; pubescence tawny; flowers purple; pods large, 2 to 2¼ inches long, tumid, crowded, shattering moderately; seeds straw-yellow, very large, 9 to 9½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

21079. *Shingto.* From Tieling, Manchuria, 1907. Plants stout, erect, bushy; height 24 to 30 inches; medium; pubescence tawny; flowers white; pods medium-sized, 1½ to 1¾ inches long, tumid, scattered, shattering little; seeds olive-yellow, medium-sized, 6½ to 7 mm. long, elliptical, slightly flattened; hilum light to slate-black; germ yellow. Grown three seasons. This variety is said to be used to produce bean oil and bean cake.

21079 A. *Auburn.* A field mass selection in 1907. Plants stout, erect, bushy; height 24 to 28 inches; medium early; pubescence gray (30 per cent) and tawny (70 per cent); flowers white; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds black, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ green. Grown two seasons.

21079 D. A field mass selection in 1907. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence tawny; flowers both purple and white; pods medium sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum dark brown; germ yellow. Grown two seasons.

21079 H. A pure field selection in 1907. Plants stout, erect, bushy, height 24 to 30 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed; crowded, shattering moderately; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown two seasons.

21080. From Tieling, Manchuria, 1907. Plants stout, erect, bushy; height 14 to 18 inches; medium; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds chromium green, medium-sized, 9 to 9½ mm. long, elliptical, slightly flattened; hilum brown; germ green. Grown three seasons. This variety is said to be the most expensive of all the soy beans at Tieling and is eaten only by the better classes of Chinese.

21080 K. A field selection in 1908. Plants stout, erect, bushy; height 22 to 26 inches; medium early; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds smoky yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown one season.

21080 L. A field selection in 1908. Plants stout, erect, bushy; height 12 to 16 inches; medium early; pubescence tawny; flowers white; pods large, 1½ to 1¾ inches long; tumid, crowded, shattering a little; seeds dark brown, large, 10 to 10½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

21080 N. A field selection in 1908. Plants stout, erect, bushy; height 12 to 16 inches; medium early; pubescence tawny; flowers both purple and white; pods medium large, 1½ to 1¾ inches long, tumid, crowded, shattering little; seeds chromium green, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown one season.

21731. *Mammoth.* From Hickory, N. C.

21754. From Vilmorin-Andrieux & Co., Paris, France, 1908. Plants stout, bushy, erect; height 10 to 14 inches; medium; pubescence tawny; flowers purple; pods medium sized, 1¾ to 2 inches long, tumid, crowded, shattering little; seeds straw-yellow, medium small, 7½ to 8 mm. long, elliptical, much flattened; hilum seal-brown; germ yellow. Grown two seasons. This variety was also obtained from Dammann & Co., Naples, Italy, and grown under S. P. I. No. 22414.

21755. From Vilmorin-Andrieux & Co., Paris, France, 1908. Plants stout, bushy, erect; height 12 to 16 inches; very early; pubescence tawny; flowers white; pods large, 2 to 2¼ inches long, tumid, half crowded, shattering moderately; seeds deep brown, medium large to large, 8 to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Except for length of season, this could not be distinguished from 17258, Ogemaw. Grown two seasons.

21756. From Vilmorin-Andrieux & Co., Paris, France, 1908. This is identical with 18227.

21757. Identical with the preceding and from the same source.

21818. From Vilmorin-Andrieux & Co., Paris, France, 1908. This could not be distinguished from Ito San, 17268.

21825. From Hokkaido, Japan, 1908. Plants stout, erect, bushy; height, 16 to 20 inches, medium early; pubescence tawny; flowers purple; pods medium-sized; 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons. This variety is said to be used principally in the manufacture of "soy," "miso," "tifu," etc. It has also been obtained again from the same place and grown under Nos. 21830 and 21831.

21830. From Hokkaido, Japan, 1908.

21831. From Hokkaido, Japan, 1908.

Both these numbers produced plants that were identical with 21825.

21946. From Buitenzorg, Java, 1908. A black-seeded variety, but the seeds failed to germinate.

21999. *Taha.* From Boshan, Shangtung, China, 1907. Plants slender, erect, the tips twining; height, 28 to 32 inches; medium late; pubescence gray (5 per cent) and tawny (95 per cent); flowers both purple and white; pods large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds black with olive saddle, large, 9 to 10 mm. long, elliptical, much flattened; hilum black; germ yellow. Grown two seasons. This is said to be a rare variety of soy bean, used by the higher classes of Chinese as a vegetable in soups.

21999 B. A mass selection out of the original seed. Plants slender, erect, the tips twining; height, 36 to 48 inches; late; pubescence tawny; flowers white; pods large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds brown, large, 8 to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

21999 C. A mass selection out of the original seed. Plants slender, erect, the tips twining; height, 42 to 48 inches; late; pubescence gray (40 per cent) and tawny (60 per cent); flowers both purple and white; pods scattered, shattering little, medium-sized, 1½ to 2 inches long, compressed; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum slate-black; germ yellow. Grown two seasons.

21999 D. A mass selection out of the original seed. Plants slender, erect, the tips twining; height, 30 to 42 inches; late; pubescence tawny; flowers both purple and white; pods large, 2¼ to 2½ inches long, tumid, half crowded, shattering little; seeds olive-yellow, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum black; germ yellow. Grown two seasons

22311 From Shanghai, China, 1908. This proved to be the same as 14952 from the same place.

22312. *Farnham.* From Shanghai, China, 1908. Plants stout, erect, bushy; height 36 to 40 inches; late; pubescence gray; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, scattered, shattering moderately; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

22317. From Haage & Schmidt, Erfurt, Germany, 1908. A yellow-seeded sort, but the seed did not germinate.

22318. From Erfurt, Germany, 1908. Plants stout, erect, bushy; height, 24 to 32 inches; very late; pubescence gray; flowers white; pods medium-sized, 1½ to 1¾ inches long, tumid, scattered, shattering little; seeds straw-yellow, medium-sized; 8 to 8½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

22318 A. A field selection in 1908. Plants stout, erect, bushy; height 36 to 40 inches; late; pubescence gray; flowers white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds straw-yellow, medium small, 5½ to 6 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown one season.

22319. From Haage & Schmidt, Erfurt, Germany, 1908. A brown-seeded variety, but the seed did not germinate.

22320. From Haage & Schmidt, Erfurt, Germany, 1908, as "Green from Samarow." Identical with Guelph, 17261.

22321. From Haage & Schmidt, Erfurt, Germany. Identical with Chernie, 18227.

22322. From Haage & Schmidt, Erfurt, Germany, 1908, as "Early Black from Podolia." The same thing as Buckshot, 17251.

22333. *Baird.* The progeny of 17256 A. Selected out of 17256, grown from 6414 from Pingyang, Korea, 1901. Plants stout, erect, bushy; height 30 to 36 inches; late; pubescence gray; flowers both purple and white; pods medium small, 1¼ to 1½ inches long, tumid, half crowded, shattering little; seeds brown, medium small, 5½ to 6 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown nine seasons.

22334. From the Illinois Agricultural Experiment Station, 1908. Identical with Nuttall, 17253, and, as the records show, grown from seed obtained from the Department of Agriculture.

22335. From the Illinois Agricultural Experiment Station, 1908. Plants stout, erect, bushy; height 16 to 20 inches; medium; pubescence gray and tawny; flowers white; pods medium-sized, 1¼ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 6½ to 7 mm. long, oval; hilum pale; germ yellow. Grown two seasons.

22336. From the Illinois Agricultural Experiment Station, 1908. Both this and 22337 proved to be identical with Guelph, 17261.

22336 A. A pure field selection in 1908. Plants stout, erect, bushy; height 12 to 15 inches; medium early; pubescence tawny; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, half crowded, shattering moderately; seeds black, medium-sized, 8 to 8½ mm. long, elliptical, much flattened; hilum pale; germ green. Grown one season.

22337. See 22336.

22379. *Swan.* From Canton, Kwangtung, China, 1908. Plants stout, erect, bushy; height 26 to 30 inches; medium; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, half crowded, shattering moderately; seeds straw-yellow, medium-sized, 6½ to 7 mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

22380. From Canton, Kwangtung, China, 1908. Plants slender, erect, the tips twining; height 30 to 36 inches; late; pubescence tawny; flowers white; pods large, 2 to 2½ inches long, compressed, scattered, shattering moderately; seeds black, large, 7½ to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown two seasons.

22381. From Canton, Kwangtung, China, 1908. Plants stout, erect, bushy; height 18 to 24 inches; late; pubescence gray (25 per cent) and tawny (75 per cent); flowers both purple and white; pods medium large, 2 to 2½ inches long, tumid, crowded, shattering moderately; seeds olive-yellow, medium-sized; 7½ to 8 mm. long, oval; hilum pale; germ yellow. Grown two seasons.

22381 B. A pure selection in 1908. Plants stout, erect, bushy; height 12 to 16 inches; medium early; pubescence tawny; flowers white; pods large, 2 to 2¼ inches long, tumid, half crowded, shattering little; seeds olive-yellow (smoky), large, 9½ to 10 mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown one season.

22406. *Hongkong.* From Hongkong, Kwangtung, China, 1908. Plants stout, erect, bushy; height 24 to 30 inches; medium late; pubescence tawny; flowers both purple and white; pods scattered, shattering little, 1¾ to 2 inches long, tumid; seeds black, medium-sized, 7½ to 8 mm. long, oblong, slightly flattened; hilum pale; germ green. Grown two seasons.

22407. *Nigra.* From Hongkong, China, 1908. Plants slender, erect, the tips twining; height 24 to 30 inches; medium; pubescence gray (8 per cent) and tawny (20 per cent); flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering moderately; seeds black, medium-sized, 8½ to 9 mm. long, oblong, much flattened; hilum pale; germ green. Grown two seasons.

22411. From Dammann & Co., Naples, Italy, 1908, as "Samarow." This proved to be identical with 17260.

22411 A. A pure field selection in 1907. Plants stout, erect, bushy; height 12 to 16 inches; medium early; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, compressed, crowded, shattering much; seeds dull brown, very small, 5 to 5½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

22412. From Dammann & Co., Naples, Italy, 1908. The plants were exactly like Chernie, 18227.

22413. From Dammann & Co., Naples, Italy. Seeds brown, but none germinated.

22414. From Dammann & Co., Naples, Italy, 1908. This is exactly the same variety as 21754.

22415. From Dammann & Co., Naples, Italy, as "Giant Yellow." The plants and seeds of this can not be distinguished from Butterball, 17273.

22428. Wild soy bean from the botanic gardens, Tokyo, Japan, 1908. Plants very slender, very vining, procumbent; length of stems 36 to 48 inches; very late; pubescence tawny; flowers purple; pods small, ¾ to 1⅛ inches long, compressed, scattered, shattering very much; seeds dull black, oblong, much flattened, very small, 3½ to 4 mm. long; hilum pale; germ yellow. Grown three seasons. (See Pl. I.) No. 25138, from Soochow, Kiangsu, China, is identical. (See Pl. II, fig. 1.) This is the wild form of the soy bean. It volunteers very readily at Arlington Experimental Farm, the seedlings appearing about May 1. Were it not that the seed shatters so badly, the plant would have promise as a cover crop.

22498. From Hangchow, Chekiang, China, 1908. Plants stout, erect, bushy; height 16 to 20 inches; very late; pubescence tawny; flowers purple; pods scattered, never fully maturing at Arlington Experimental Farm; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum dark brown; germ yellow. Grown two seasons.

22499. From Hangchow, Chekiang, China. Seeds straw-yellow, but none germinated.

22500. From Hangchow, Chekiang, China, 1908. Plants stout, erect, bushy; height 24 to 28 inches; very late; pubescence tawny; flowers white; pods half crowded; seeds chromium green, medium-sized, 9 to 10 mm. long, elliptical, slightly flattened; hilum brown; germ green. Grown two seasons.

22501. From Hangchow, China, 1908. Plants slender, erect, the tips twining; height 42 to 48 inches; very late; pubescence tawny; flowers white; pods medium large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds black, medium large, 7 to 7½ mm. long, subglobose; hilum pale; germ green. Grown two seasons.

22503. From Yokohama, Japan, 1908. Plants stout, erect, bushy; height 12 to 16 inches; medium; pubescence gray; flowers purple; pods large, 2¼ to 2½ inches long, tumid, crowded, shattering moderately; seeds straw-yellow, large, 9½ to 10 mm. long, subglobose; hilum pale; germ yellow. Grown two seasons.

22504. From Yokohama, Japan, 1908. Plants stout, erect, bushy; height 18 to 24 inches; late; pubescence tawny; flowers purple; pods large, 2¼ to 2½ inches long, tumid, crowded, shattering much; seeds olive-yellow, large, 8 to 9 mm. long, subglobose; hilum pale; germ yellow. Grown two seasons.

22504 A. A selection out of the original seed 22504, Plants stout, erect, bushy; height 14 to 18 inches; medium; pubescence gray; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, crowded, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

22505. From Yokohama, Japan, 1908. Plants stout, erect, bushy; height 20 to 28 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, tumid, crowded, shattering little; seeds straw-yellow, medium-sized, 6½ to 7½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

22506. From Yokohama, Japan, 1908. Plants stout, erect, bushy; height 12 to 16 inches; medium; pubescence gray; flowers purple; pods medium large, 2 to 2¼ inches long, tumid, crowded, shattering much; seeds straw-yellow, medium-sized, 8½ to 9 mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown two seasons.

22507. From Yokohama, Japan, 1908. Plants stout, erect, bushy; height, 18 to 22 inches; medium; pubescence tawny; flowers white; pods medium-sized, 1½ to 1¾ inches long, tumid, crowded, shattering much; seeds olive-yellow, medium large, 8½ to 9 mm. long, subglobose; hilum brown; germ yellow. Grown two seasons.

22534. From Weihsien, China, 1908. Plants slender, erect, the tips twining; height, 36 to 42 inches; late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering moderately; seeds straw-yellow, medium small, 7½ to 8 mm. long, oval; hilum brown; germ yellow. Grown two seasons. This variety is said to be used for making lamp and cooking oil and for flour to make cakes. The remaining material after expressing the oil forms a cake which is exported for feeding animals and enriching land.

22535. From Weihsien, China, 1908. The seeds and plants of this are identical with Cloud, 16790.

22536. From Chefoo, Shantung, China, 1908. This proved identical with 17857.

22537. From Chefoo, Shantung, China, 1908. Plants stout, erect, bushy; height, 18 to 30 inches; late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium-sized, 8½ to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons. This variety is said to be used quite extensively at Chefoo for the manufacture of oil.

22538. From Chefoo, Shantung, China, 1908. Plants slender, erect, the tips twining; height, 36 to 42 inches; medium late; pubescence gray (50 per cent) and tawny (50 per cent); flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering moderately; seeds black, medium-sized, 6 to 6½ mm. long, oblong, much flattened; germ yellow. Grown two seasons.

22633. *Morgan.* From Sheklung, Kwangtung, China, 1908. Plants slender, erect, the tips twining; height, 36 to 42 inches; very late; pubescence tawny; flowers both purple and white; pods medium small, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds olive-yellow, small, 5½ to 6 mm. long, elliptical, much flattened; hilum russet; germ yellow. Grown two seasons.

22634. From Sheklung, Kwangtung, China, 1908. Plants stout, erect, bushy; height, 22 to 28 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1¼ to 1¾ inches long, half crowded; shattering moderately; seeds black, medium small, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

22644. *Stuart.* From Hangchow, Chekiang, China, 1908. Plants stout, erect, bushy; height, 36 to 40 inches; very late; pubescence gray; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds olive-yellow, medium small, 7 to 7½ mm. long, elliptical, much flattened; hilum russet; germ yellow. Grown two seasons.

22644 A. A pure field selection in 1908. Plants stout, erect, bushy; height, 36 to 42 inches; very late; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds seal-brown to olive, medium small, elliptical, 6½ to 7 mm. long, much flattened; hilum pale; germ yellow. Grown one season.

22644 B. *Nielsen.* A pure selection out of the original seed of 22644. Plants stout, erect, bushy; height, 34 to 38 inches; very late; pubescence gray; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum burnt umber; germ yellow. Grown two seasons.

22644 C. A selection in 1908. Plants stout, erect, bushy; height, 24 to 30 inches; very late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, compressed, scattered, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown one season.

22645. From Hangchow, Chekiang, China, 1908. Plants stout, erect, bushy; height, 16 to 20 inches; medium; pubescence tawny; flowers purple; pods medium large, 2 to 2¼ inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum bister brown; germ yellow. Grown two seasons.

22646. From Hangchow, Chekiang, China, 1908. Plants stout, erect, bushy; height, 30 to 36 inches; very late; pubescence gray; flowers purple; medium-sized pods large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds olive-yellow, large, 8 to 9 mm. long, elliptical, much flattened; hilum russet; germ yellow. Grown two seasons.

22714. From Saigon, Cochin China, 1908. Plants stout, erect, bushy; height, 30 to 36 inches; very late; pubescence gray; flowers both purple and white; pods scattered; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum light brown; germ yellow. Grown two seasons.

22874. *Vireo.* From Tokyo, Japan, 1908. Plants stout, erect, bushy; height, 14 to 18 inches; early; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, tumid, crowded, shattering little; seeds olive-yellow, medium small, 6 to 6½ mm. long, elliptical, slightly flattened; hilum slate-color; germ yellow; leaves persist when pods are ripening. Grown two seasons.

22875. From Tokyo, Japan, 1908. This proved the same as Flat King, 17252.

22876. From Tokyo, Japan, 1908. Plants stout, erect, bushy; height, 16 to 22 inches; medium; pubescence gray and very sparse; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow, small to medium, 6½ to 7½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

22877. From Tokyo, Japan, 1908. This was found to be the same as Okute, 19986.

22878. From Tokyo, Japan, 1908. This did not differ in any respect from 17273.

22879. From Tokyo, Japan, 1908. Plants stout, erect, bushy; height, 20 to 26 inches; medium; pubescence gray; flowers both purple and white; pods medium small, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium small, 6½ to 7 mm. long, elliptical, much flattened; hilum light to seal-brown; germ yellow. Grown two seasons.

22880. From Tokyo, Japan, 1908. Plants stout, erect, bushy; height, 18 to 22 inches; medium; pubescence gray (60 per cent) and tawny (40 per cent); flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum pale to brown; germ yellow. Grown two seasons.

22880 A. A selection in 1908. Plants stout, erect, bushy; height, 28 to 32 inches; medium early; pubescence gray; flowers both purple and white; pods medium large, 2 to 2¼ inches long, tumid, scattered, shattering little; seeds straw-yellow (cloudy saddle); medium large, 8 to 8½ mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown one season.

22880 B. A selection in 1908. Plants stout, erect, bushy; height, 12 to 16 inches; medium early; pubescence gray; flowers purple; pods medium-sized, 1½ to 2 inches long, compressed, crowded, shattering little; seeds chromium green, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum brown; germ green. Grown one season.

22880 C. A selection in 1908. Plants stout, erect, bushy; height, 14 to 18 inches; yellow; pubescence tawny; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow (cloudy); medium-sized, 6½ to 7 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown one season.

22881. From Tokyo, Japan, 1908. Identical with Hope, 17267.

22882. From Tokyo, Japan, 1908. Identical with 19981.

22883. From Tokyo, Japan, 1908. Identical with 19987.

22884. From Tokyo, Japan, 1908. Identical with Butterball, 17273.

22885. From Tokyo, Japan, 1908. Identical with 19981.

22886. From Swatow, Kwantung, China, 1908. Identical with Ebony, 17254.

22897. *Columbia.* From Paotingfu, Chihli, China, 1908. Plants stout, erect, bushy; height, 28 to 34 inches; late; pubescence gray; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, crowded, shattering little; seeds chromium green, small, 7 to 7½ mm. long, elliptical, slightly flattened; hilum light brown; germ green. Grown two seasons.

22898. From Paotingfu, Chihli, China, 1908. This was grown in 1908 and found to be indistinguishable from Sherwood, 17862.

22898 A. *Lowrie.* A field mass selection in 1908. Plants stout, erect, bushy; height 30 to 34 inches; medium; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, tumid, scattered, shattering little; seeds olive-yellow, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum light to slate-black; germ yellow. Grown one season.

22899. *Arlington.* From Paotingfu, Chihli, China, 1908. Plants slender, erect, the tips twining; height 30 to 36 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¼ to 1¾ inches long, compressed, scattered, shattering moderately; seeds black, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons. This variety is said to be boiled as a fodder for horses and mules. Oil is also expressed out of it and the remaining material used as fertilizer.

22899 A. A mass selection out of the original seed. Plants slender, suberect, the tips twining; stems 48 to 56 inches long; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed; seeds black, medium-sized, 7 to 7½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

22900. From Paotingfu, Chihli, China, 1908. Plants slender, erect, the tips twining; height 30 to 40 inches; late; pubescence tawny; flowers both purple and white; pods large, 1¾ to 2 inches long, tumid, scattered, shattering moderately, seeds black, large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown two seasons.

22901. From Paotingfu, Chihli, China, 1908. Plants stout, erect, bushy; height 24 to 30 inches; medium; pubescence gray (40 per cent) and tawny (60 per cent); flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds straw-yellow, small to medium small, 6 to 7 mm. long, elliptical, much flattened; hilum slate-black; germ yellow. Grown two seasons.

22919. From Ingchung, Fukien, China, 1908. Plants slender, erect, the tips twining; height 36 to 48 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, tumid, scattered, shattering much; seeds black, medium-sized, 6½ to 7 mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown two seasons.

22920. From Ingchung, Fukien, China, 1908. Plants stout, erect, bushy; height 16 to 24 inches; medium late; pubescence gray; flowers both purple and white; pods large, 2 to 2¼ inches long, tumid, half crowded, shattering moderately; seeds olive-yellow, medium large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

22920 A. A selection out of the original seed. Plants slender, erect, the tips twining; height 32 to 36 inches; medium late; pubescence tawny; flowers both purple and white; pods medium large, 1¾ to 2⅕ inches long, tumid, scattered, shattering little; seeds olive-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum light to seal-brown; germ yellow. Grown two seasons.

22921. From Ingchung, Fukien, China, 1908. Plants slender, suberect, the tips twining; height 36 to 48 inches; medium late; pubescence gray (50 per cent) and tawny (50 per cent); flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering much; seeds straw-yellow, medium small to medium, 6 to 7½ mm. long, elliptical, much flattened; hilum black; germ yellow. Grown two seasons.

22921 A. A mass selection in 1908. Plants slender, erect, the tips twining; height 18 to 24 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering much; seeds straw-yellow, medium small to medium, 7½ to 8 mm. long, oval, slightly flattened; hilum raw umber; germ yellow. Grown one season.

22921 B. A selection in 1908. Plants stout, erect, bushy; height 12 to 18 inches; late; pubescence tawny; flowers white; pods medium large, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds straw-yellow, large, 7 to 7½ mm. long, elliptical, much flattened; hilum black; germ yellow. Grown one season.

22922. From Ingchung, Fukien, China, 1908. Plants stout, erect, bushy; height 30 to 34 inches; medium; pubescence gray; flowers both purple and white; pods medium large, 1½ to 1¾ inches long, tumid, half crowded, shattering little; seeds straw-yellow; medium large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum light to dark brown; germ yellow. Grown two seasons.

22922 A. A field mass selection in 1908. Plants stout, erect, bushy; height 30 to 36 inches; medium late; pubescence gray; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, tumid, scattered, shattering moderately; seeds straw-yellow, medium-sized, 7½ to 8 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown one season.

22927. From Shanghai, Kiangsu, China, 1908. Plants slender, erect, the tips twining; height 36 to 42 inches; late; pubescence tawny; flowers both purple and white; pods large, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds black, large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown two seasons.

23205. From Shanghai, Kiangsu, China, 1908. Plants stout, erect, bushy; height 24 to 30 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds black, medium small, 6½ to 7 mm. long, elliptical, much flattened; germ yellow. Grown one season. This is said to be an important bean for dry rice land.

23207. From Soochow, Kiangsu, China, 1908. Plants stout, erect, bushy; height 24 to 28 inches; very late; pubescence tawny; flowers white; pods half crowded; seed solive-yellow, large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum slate-black; germ yellow. Grown one season.

23207 B. A pure selection out of the original seed. Plants stout, erect, bushy; height 30 to 34 inches; very late; pubescence tawny; flowers white; pods large, 2¼ to 2¾ inches long, compressed, crowded, shattering little; seeds straw-yellow, large, 9 to 9½ mm. long, elliptical, much flattened; hilum seal-brown; germ yellow. Grown one season.

23208. From Tangsi, Chekiang, China, 1908. Plants slender, suberect, the tips twining; height 30 to 36 inches; very late; pubescence gray; flowers purple; pods large, half crowded; seeds straw-yellow, large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown one season.

23209. From Tangsi, Chekiang, China, 1908. Plants stout, erect, bushy; height 24 to 28 inches; very late; pubescence gray and tawny; flowers purple; pods medium large, 2 to 2¼ inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow. Grown two seasons.

23209 A. A pure selection out of the original seed. Plants stout, erect, bushy; height 36 inches; very late; pubescence tawny; flowers white; pods medium-sized, 2 to 2¼ inches long, compressed, scattered, shattering little; seeds chromium green, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum brown; germ green. Grown one season.

23211. From Tangsi, Chekiang, China, 1908. Plants slender, erect, the tips twining; height 30 to 36 inches; very late; pubescence both gray and tawny; flowers purple; pods large, 2 to 2½ inches long, compressed, half crowded, shattering little; seeds deep brown, medium large, 7 to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

23212. From Hangchow, Chekiang, China, 1908. Seeds yellow, but none germinated.

23213. From Hangchow, Chekiang, China, 1908. Plants slender, erect, the tips twining; height 24 to 30 inches; very late; pubescence tawny; flowers purple; pods half crowded; seeds straw-yellow, large, 8 to 8½ mm. long, oval; hilum prominent seal-brown; germ yellow. Grown one season.

23213 A. A selection out of the original seed. Plants stout, erect, bushy; height 20 to 24 inches; very late; pubescence tawny; flowers purple and white; pods half crowded; seeds yellow and black, medium large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown one season.

23229. *Sedo.* From Tientsin, Chihli, China, 1908. Plants stout, erect, bushy; height 20 to 26 inches; medium; pubescence tawny; flowers purple; pods medium large, 1¾ to 2¼ inches long, tumid scattered, shattering little; seeds deep brown, very large, 9 to 10 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons. This variety is said to be rare and used only for human food.

28232. From Chinhuafu, Kiangsu, China, 1908. Plants slender, erect, the tips twining; height 34 to 40 inches; very late; pubescence tawny; flowers purple; pods small, 1⅛ to 1½ inches long, compressed, scattered, shattering little; seeds dull brown, small, 5½ to 6 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons. This variety is said to be grown on wet rice lands throughout central China.

23291. From Wutaishan, Shansi, China, 1908. Plants slender, erect, the tips twining; height 30 to 42 inches; medium late; pubescence gray (50 per cent) and tawny (50 per cent); flowers purple; pods medium small, 1¼ to 1¾ inches long, compressed, scattered, shattering little; seeds black, medium-sized, 7 to 8 mm. long, oblong, much flattened; germ yellow. Grown one season. "This variety is considered by the Chinese to be the best food for their hard-working horses and mules."

23292. From Wutaishan, Shansi, China, 1908. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds small to medium, 7½ to 8 mm. long, elliptical, much flattened; hilum brown. Grown two seasons. This variety is said to be used all through northern China for making bean curd and bean vermicelli.

23292 A. A selection out of the original seed. Plants stout, erect, bushy; height 26 to 30 inches; medium; pubescence tawny; flowers purple; pods medium-sized; 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds medium-sized, 7 to 8 mm. long, oblong, much flattened; germ yellow. Grown one season.

23292 B. A selection out of the original seed. Plants slender, erect, the tips twining; height 24 to 30 inches; medium; pubescence tawny; flowers purple; pods medium-sized, 1½ to 2 inches long, compressed, half crowded, shattering moderately; seeds brown, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown one season.

23292 C. A selection out of the original seed. Plants stout, erect, bushy; height 28 to 34 inches; late; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds chromium green, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum seal-brown; germ green. Grown one season.

23296. From Taichow, Chekiang, China, 1908. A variety found growing on strongly alkaline lands. Plants stout, erect, bushy; height 30 to 36 inches; medium; pubescence tawny; flowers both purple and white; pods medium sized, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds straw-yellow, medium-sized, 8½ to 9 mm. long, elliptical much flattened; hilum slate-black; germ yellow. Grown two seasons.

23296 A. A selection out of the original seed. Plants stout, erect, bushy; height 24 to 30 inches; medium late; pubescence tawny; flowers white; pods medium large, 1¾ to 2 inches long, compressed, half crowded, shattering moderately; seeds chromium green, medium large, 9 to 10 mm. long, elliptical, much flattened; hilum bister brown; germ green. Grown one season.

23296 C. A selection out of the original seed. Plants stout, erect, bushy; height 20 to 24 inches; medium; pubescence gray; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, half crowded, shattering little; seeds black, medium-sized, 8½ to 9 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown one season.

23297. From Taichow, China, 1908. Plants slender, erect, the tips twining; height 28 to 34 inches; medium late; pubescence gray and tawny; flowers purple, pods medium-sized, 1¾ to 2 inches long, compressed, half-crowded, shattering little; seeds black, medium-sized, 7½ to 8 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown two seasons.

23297 A. A selection out of the original seed. Plants slender, erect, the tips twining; height 30 to 36 inches; medium late; pubescence tawny; flowers both purple and white; pods large, 1¾ to 2¼ inches long, tumid, half crowded, shattering little; seeds brown, large, 8 to 8½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown one season.

23297 B. A selection out of the original seed. Plants slender, suberect, the tips twining; height 30 to 36 inches; medium late; pubescence tawny; flowers both purple and white; pods medium-sized, 1½ to 2 inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium-sized, 8½ to 9 mm. long, oblong, much flattened; hilum slate-black; germ yellow. Grown two seasons.

23299. From Tsintse, China, 1908. Plants slender, erect, the tips twining; height 42 to 48 inches; late; pubescence tawny; flowers purple; pods large, 2 to 2¼ inches long, tumid, scattered, shattering little; seed black with yellow saddle, large, 9 to 9½ mm. long, elliptical, much flattened; hilum black; germ yellow. Grown one season. This is said to be a rare local variety of soy bean used as a vegetable when slightly sprouted.

23303. From Shiling, Chihli, China, 1908. Plants stout, erect, bushy; height 14 to 30 inches; medium late; pubescence gray (70 per cent) and tawny (30 per cent); flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum brown to nearly black; germ yellow. Grown two seasons. This variety is said to be used all through northern China for making bean curd and bean vermicelli.

23303 A. A selection out of the original seed. Plants stout, erect, bushy; height 20 to 24 inches; medium late; pubescence tawny; flowers purple; pods medium large, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds chromium green, medium-sized; 8 to 8½ mm. long, elliptical, slightly flattened; hilum black; germ green. Grown one season.

23305. From Peking, Chihli, China, 1908. Seeds yellow, but all failed to germinate.

23306. From Peking, Chihli, China, 1908. Plants stout, erect, bushy; height 30 to 36 inches; medium late; pubescence tawny; flowers white; pods large, 1¾ to 2 inches long, tumid, half crowded, shattering little; seeds black, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown one season.

23311. From Shiling, Chihli, China, 1908. Plants slender, erect, the tips twining; height 36 to 40 inches; late; pubescence tawny; flowers white; pods medium large, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds chromium green, medium large, 7½ to 8½ mm. long, elliptical, slightly flattened; hilum slate-black; germ green. Grown one season.

23311 A. Selected out of the original seed. Plants slender, erect; height 32 to 36 inches; medium late; pubescence tawney; flowers both purple and white; pods medium-sized, 1½ to 1¾ inches long, compressed, shattering little; seeds black, medium small, 7 to 7½ mm. long, oblong, much flattened; hilum pale; germ yellow. Grown one season.

23311 B. A selection out of the original seed. Plants stout, erect, bushy; height 30 to 36 inches; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2 inches long, tumid, crowded, shattering little; seeds black and yellow, medium small, 7 to 7½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown one season.

23312. From Paotingfu, Chihli, China, 1908. Plants slender, erect; height 24 to 30 inches; medium late; pubescence gray; flowers both purple and white; pods medium small, 1¼ to 1½ inches long, tumid, shattering little; seeds olive-yellow, small, 6 to 6½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown two seasons.

23325. From Canton, Kwangtung, China, 1908. Plants stout, erect, bushy; height 12 to 16 inches; medium late; pubescence tawny; flowers purple; pods medium small, 1½ to 1¾ inches long, tumid, crowded, shattering moderately; seeds black, small, 6 to 6½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

23326. From Canton, Kwangtung, China. Seeds olive-yellow; all failed to germinate.

23327. From Canton, Kwangtung, China, 1908. Seeds olive-yellow; none germinated.

23336. From Shanghai, Kiangsu, China, 1908. This is the same as 20798, secured at the same place.

23337. From Shanghai, Kiangsu, China, 1908. Identical with 20797, from the same place.

23338. From Shanghai, Kiangsu, China, 1908. Plants slender, erect, very leafy; height 48 to 60 inches; very late; pubescence tawny; flowers purple; pods medium-sized, 1½ to 2 inches long, tumid, scattered, shattering little; seeds brown with more or less black usually in concentric bands, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season. Notes taken at Jackson, Tenn.

23338 B. A selection out of the original seed. Plants slender, erect, the tips twining; height 30 to 40 inches; very late; pubescence tawny; flowers purple; pods scattered; seeds black, large, 8 to 9 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

23522. From Chungking, Szechwan, China, 1908. Seeds olive-yellow; none germinated.

23523. From Chungking, Szechwan, China, 1908. Plants stout, erect, bushy; height 14 to 20 inches; late; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, tumid, crowded, shattering moderately; seeds black, medium-sized, 6½ to 7½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

23544. From Ningyuenfu, Szechwan, China, 1908. Seeds yellow; none viable.

23545. From Ningyuenfu, Szechwan, China, 1908. Seeds yellow; none grew.

23546. From Ningyuenfu, Szechwan, China, 1908. Plants stout, erect, bushy; height 38 to 42 inches; very late; pubescence tawny; flowers purple; pods small, 1⅛ to 1½ inches long, compressed, scattered, shattering little; seeds black, very small, 5 to 5½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

24180. From Soochow, Kiangsu, China, 1908. Plants stout, erect, bushy; height 14 to 20 inches; medium late; pubescence tawny; flowers purple; pods large, 2¼ to 2½ inches long, tumid, crowded, shattering moderately; seeds black, large, 9 to 9½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

24181. From Soochow, Kiangsu, China, 1908. Plants stout, erect, bushy; height 18 to 24 inches; medium; pubescence gray; flowers purple; pods medium-sized, 1¾ to 2 inches long, tumid, half-crowded, shattering little; seeds straw-yellow, medium large, 8 to 8½ mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown one season.

24182. From Soochow, Kiangsu, China, 1908. Seeds green; none viable.

24183. From Soochow, Kiangsu, China, 1908. Plants stout, erect, bushy; height 16 to 20 inches; medium late; pubescence gray; flowers purple; pods large, 2 to 2¼ inches long, tumid, crowded, shattering little; seeds olive-yellow, medium-sized, 9 to 9½ mm. long, elliptical, slightly flattened; hilum brown; germ yellow; leaves persist when pods are ripening. Grown one season.

24184. From Soochow, Kiangsu, China, 1908. Plants slender, erect, the tips twining; height 36 to 42 inches; late; pubescence gray; flowers purple; pods medium-sized, 1½ to 2 inches long, compressed, scattered, shattering little; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown one season.

24610. *Trenton.* From Trenton, Ky. Found by Mr. S. J. Leavell in a field of the Mammoth variety in 1904. Plants stout, erect, bushy; height 32 to 38 inches; late; pubescence gray; flowers white; pods medium-sized, 1½ to 2 inches long, compressed, scattered, shattering little; seeds brown, medium small, 6½ to 7 mm. long, elliptical, much flattened; hilum pale; germ yellow. Except for color and shape of seeds, this variety is indistinguishable from Mammoth, 17280. Grown one season.

24641. From Taihoku, Formosa, 1909. Seeds yellow; all failed to germinate.

24642. From Taihoku, Formosa, 1909. Plants procumbent, vining, rather coarse; stems 52 to 60 inches long; very late; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, tumid, scattered, shattering little; seeds black, small, 5 to 5½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season. A variety identical with this was received under No. 24643 (Taihoku, Formosa).

24643. From Taihoku, Formosa, 1909. Seeds black; none grew.

24672. From Khasi Hills, Assam, India, 1909. Plants stout, erect, bushy; height 42 to 48 inches; very late; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds yellow, clouded with brown, small, 5½ to 6 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown one season.

24672 A. A selection out of the original seed. Plants slender, erect, the tips twining; height 36 to 42 inches; very late; pubescence tawny; flowers purple; pods small, 1⅛ to 1½ inches long, tumid, scattered, shattering little; seeds brown, small, 5½ to 6 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

24672 B. A selection out of the original seed. Plants stout, erect, bushy; height 24 to 32 inches; very late; pubescence tawny; flowers purple; pods small, 1 to 1¼ inches long, tumid, scattered, shattering little; seeds straw-yellow, small, 5½ to 6 mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown one season.

24673. From Darjiling, Assam, India, 1909. Plants procumbent, vining, rather coarse; stems 48 to 60 inches long; very late; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds brown, small, 5 to 5½ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

24674. From Darjiling, Assam, India, 1909. Plants procumbent, vining, rather coarse; stems 48 to 56 inches long; very late; pubescence tawny; flowers purple; pods medium small, 1¼ to 1¾ inches long, compressed, scattered, shattering little; seeds straw-yellow, small, 6 to 6½ mm. long, elliptical, much flattened; hilum brown; germ yellow. Grown one season.

24675. From Safipur, Unao, United Provinces, India, 1909. Plants procumbent, vining, rather coarse; stems 48 to 60 inches long; very late; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds black, small, 5½ to 6 mm. long, oblong, much flattened; germ yellow. Grown one season. The following lots, all from India, were found to be identical with this: 24676, from Hasangani; 24677, from Ranjitpurwa; 24678, 24679, 24680, 24683, 24686, from Etawah; 24681, from Mainpuri; 24688, from Cawnpore; 24689, from Dehra Dun.

24676. From Hasangani, Unao, U. P., India. Identical with 24675.

24677. From Ranjitpurwa, Unao, U. P., India. Identical with 24675.

24678. From Etawah, Unao, U. P., India. Identical with 24675.

24679. From Etawah, Unao, U. P., India. Identical with 24675.

24680. From Etawah, Unao, U. P., India. Identical with 24675.

24681. From Mainpuri, U. P., India. Identical with 24675.

24682. From Mainpuri, U. P., India, 1909. Plants stout, erect, bushy; height 18 to 24 inches; very late; pubescence tawny; flowers purple; pods small, 1¼ to 1½ inches long, compressed, scattered, shattering little; seeds black, very small, 5 to 5½ mm. long, oblong, much flattened; germ yellow. Grown one season. Nos. 24684 and 24685, from Etawah, India, are identical with this variety.

24683. From Etawah, Unao, U. P., India. Identical with 24675.

24684. From Etawah, Unao, U. P., India. Identical with 24682.

24685. From Etawah, Unao, U. P., India. Identical with 24682.

24686. From Etawah, Unao, U. P., India. Identical with 24675.

24687. From United Provinces, India. Did not germinate.

24688. From Cawnpore, India. This proved to be identical with No. 24675.

24689. From Cawnpore, India. This is identical with No. 24675.

24690. From Dehra Dun, U. P., India. Did not germinate.

24693 to 24711, inclusive. Nineteen Japanese varieties of soy beans grown on Poona Farm, Bombay Presidency, India. All of these failed to germinate, except 24695.

24695. From Poona, Bombay, India, 1909, originally from Japan. Plants stout, erect, bushy; height 28 to 32 inches; late; pubescence gray; flowers purple; pods medium-sized, 1¾ to 2 inches long, compressed, crowded, shattering little; seeds straw-yellow, medium-sized, 7 to 7¼ mm. long; elliptical, much flattened; hilum pale; germ yellow. Grown one season.

24839. From Shanghai, Kiangsu, China, 1906. Plants stout, erect, bushy; height 32 to 36 inches; very late; pubescence tawny; flowers white; pods large, 2¼ to 2½ inches long, compressed, scattered, shattering little; seeds olive-yellow, medium large, 7½ to 8 mm. long; elliptical, slightly flattened; hilum slate-black; germ yellow. Grown four seasons.

24840. From Shanghai, China, 1906. Plants stout, erect, bushy; height 32 to 36 inches; very late; pubescence gray; flowers purple; pods large, 1¾ to 2¼ inches long, tumid, scattered, shattering little; seeds straw-yellow, large, 8½ to 9 mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown three seasons.

25093. *Mammoth.* From Hickory, N. C.

25118. From Pithoragarh, Kumaon District, India, 1909. Plants procumbent, vining, rather coarse; stems 48 to 60 inches long; very late; pubescence tawny; flowers purple; pods small, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds black, marbled with brown, small, 5 to 6 mm. long, oblong, much flattened; hilum pale; germ yellow. Grown one season.

25130. *Early Brown.* From Knoxville, Tenn, 1909. Plants stout, erect, bushy; height 18 to 24 inches; medium early; pubescence tawny; flowers purple; pods medium-sized, 2 to 2⅛ inches long, tumid, half crowded, shattering little; seeds brown, medium-sized, 7½ to 8 mm. long, elliptical, much flattened; hilum pale; germ yellow. Except for color of seeds and maturity, this variety is difficult to distinguish from Ito San, 17268. Grown one season. No. 25161, from the Indiana Agricultural Experiment Station, is the same.

25131. From Knoxville, Tenn., 1909. Plants stout, erect, bushy; height 30 to 36 inches; medium late; pubescence tawny; flowers purple; pods medium-sized, 1¾ to 2½ inches long, compressed, half crowded, shattering much; seeds straw-yellow, medium-sized, 7 to 7½ mm. long, elliptical, much flattened; hilum light brown; germ yellow. Grown one season.

25133. From Soochow, China, 1909. Plants slender, suberect, the tips twining; stems 48 to 60 inches long; very late; pubescence both gray and tawny; flowers purple; pods scattered; seeds straw-yellow, small, 5½ to 6 mm. long, elliptical, much flattened; hilum light brown; germ yellow. Grown one season. This variety is said to be the smallest grown at Soochow, and is used only for bean sprouts.

25134. From Soochow, China, 1909. Plants slender, suberect, the tips twining; stems 36 to 42 inches long; very late; pubescence gray; flowers purple; pods large, 2½ to 2¾ inches long, compressed, scattered; seeds straw-yellow, large, 9 to 9½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown one season.

25134 A. A selection out of the original seed. Plants slender, suberect, the tips twining; stems 42 to 48 inches long; very late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¼ to 1¾ inches long, tumid, scattered, shattering little; seeds straw-yellow, medium-sized, 8 to 8½ mm. long, elliptical, slightly flattened; hilum light to dark brown; germ yellow. Grown one season.

25135. From Soochow, Kiangsu, China, 1909. Plants slender, erect, the tips twining; height 40 to 46 inches; very late; pubescence tawny; flowers purple; pods large, 2 to 2½ inches long, scattered, shattering little; seeds chromium green, large, 7½ to 8 mm. long, elliptical, slightly flattened; hilum slate-colored; germ green. Grown one season. This variety may be put to all uses of the soy, but in practice it is used only to make parched Sutt beans, eaten as a relish.

25136. From Soochow, Kiangsu, China, 1909. Plants slender, suberect, the tips twining; stems 48 to 56 inches long; very late; pubescence tawny; flowers purple; pods large, 2½ to 2¾ inches long, compressed, scattered, shattering little; seeds brown, very large, 9 to 10 mm. long; elliptical, slightly flattened; hilum pale; germ yellow. Grown one season. This variety is said to be the largest of all the soys at Soochow. It is used only for eating in the green state, but may be used for all the soy purposes.

25137. From Soochow, Kiangsu, China, 1909. Plants procumbent, vining, rather coarse; stems 36 to 42 inches long; very late; pubescence tawny; flowers purple; pods scattered; seeds brown and black, the colors concentrated in bands, large, 9 to 9½ mm. long, elliptical, slightly flattened; hilum pale; germ yellow. Grown one season.

25138. From Soochow, Kiangsu, China, 1909. This is identical with the wild soy bean, No. 22428. Grown one season. (See Pl. II, fig. 1.)

25161. *Early Brown.* From Indiana Agricultural Experiment Station, 1909. Identical with 25130.

This variety was obtained originally by the Indiana Agricultural Experiment Station from Mr. E. F. Diehl, Leesburg, Ind., who writes that he had two varieties, an Early Yellow and the Early Black, which he tested side by side. In the progeny, he noted a few seeds that were partly brown and yellow in color, the one gradually shading into the other. Out of curiosity, he selected and planted the seeds with the largest amount of brown and within a few years secured the brown-seeded variety which has been called Early Brown.

Among seeds of the Ito San variety grown at the Kansas Agricultural Experiment Station were many in which the seed was partially brown, undoubtedly due to the influence of crossing.

25162. *Mammoth.* From Columbia, Tenn.

25212. From Botanic Gardens, Bremen, Germany, 1909. This proved to be the same as 21755.

25212 A. Black seeds mixed with the preceding. Produced plants identical with Buckshot, 17251.

25437. From Yachow, Szechwan, China, 1909. Plants slender, erect, the tips twining; height 48 to 56 inches; very late; pubescence gray (60 per cent) and tawny (40 per cent); flowers white; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds straw-yellow, medium-sized, 6 to 6½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown one season.

25437 A. A selection out of the original seed. Plants stout, erect, bushy; height 32 to 38 inches; very late; pubescence tawny; flowers purple; pods medium-sized, 1½ to 1¾ inches long, compressed, scattered, shattering little; seeds chromium green, medium-sized, 6½ to 7 mm. long; elliptical, slightly flattened hilum russet; germ green. Grown one season.

25437 B. A selection from the original seed. Plants stout, erect, bushy; height 26 to 32 inches; very late; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded; shattering little; seeds black, medium-sized, 6 to 7 mm. long, elliptical, slightly flattened; hilum pale; germ green. Grown one season.

25437 C. A selection out of the original seed. Plants stout, erect, bushy; height 36 to 40 inches; very late; pubescence tawny; flowers both purple and white; pods medium-sized, 1¾ to 2 inches long, compressed, half crowded, shattering little; seeds brown, medium-sized, 6½ to 7 mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown one season.

25438. From Yachow, Szechwan, China, 1909. Plants slender, erect, the tips twining; height 30 to 36 inches; very late; pubescence tawny; flowers white; pods medium-sized, 1¾ to 2 inches long, compressed, scattered, shattering little; seeds chromium green, medium small, 6 to 7 mm. long, elliptical, slightly flattened; hilum slate-colored; germ green. Grown one season.

25438 A. A selection out of the original seed. Plants slender, erect, the tips twining; height 34 to 38 inches; very late; pubescence both gray and tawny; flowers both purple and white; pods medium large, 1¾ to 2¼ inches long, compressed, scattered, shattering little; seeds olive-yellow, medium-sized, 6½ to 7½ mm. long, elliptical, slightly flattened; hilum light brown; germ yellow. Grown one season.

25438 B. A selection out of the original seed. Plants slender, erect, the tips twining; height 36 to 40 inches; very late; pubescence both gray and tawny; flowers white; pods medium-sized, $1\frac{1}{2}$ to $1\frac{3}{4}$ inches long, compressed, scattered, shattering little; seeds straw-yellow, medium-sized, 7 to $7\frac{1}{2}$ mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown one season.

25468. *Wisconsin Black.* From L. L. Olds Seed Company, Madison, Wis., 1909, secured by that company from the Wisconsin Agricultural Experiment Station. Plants stout, erect, bushy; height 16 to 20 inches; medium; pubescence tawny; flowers purple; pods medium-sized, $1\frac{1}{2}$ to $1\frac{3}{4}$ inches long, compressed, half crowded, shattering little; seeds black, medium-sized, 8 to $8\frac{1}{2}$ mm. long, elliptical, much flattened; hilum pale; germ yellow. Grown nine seasons. This variety has proved to be one of the earliest growing in Wisconsin. While the records are somewhat incomplete, it is almost certainly the direct descendant of S. P. I. No. 5039, received from Vilmorin-Andrieux & Co., Paris, France, 1900.

27498. From Peking, Chihli, China, 1909. Plants slender, erect, the tips twining; height 42 to 48 inches; late; pubescence gray; flowers both purple and white; pods medium-sized, $1\frac{1}{4}$ to $1\frac{3}{4}$ inches long, tumid, half crowded, shattering little; seeds chromium green, medium-sized, 7 to $7\frac{1}{2}$ mm. long, elliptical, slightly flattened; hilum black; germ green. Grown one season.

27499. From Ingang, Fukien, China, 1909. Plants slender, erect, the tips twining; height 36 to 42 inches; very late; pubescence tawny; flowers purple; pods scattered; seeds straw-yellow, $5\frac{1}{2}$ to 6 mm. long, elliptical, slightly flattened; hilum seal-brown; germ yellow. Grown one season.

27500. From Shanghai, Kiangsu, China, 1909. Plants stout, erect, bushy; height 26 to 32 inches; very late; pubescence tawny; flowers purple; pods medium large, 2 to $2\frac{1}{4}$ inches long, compressed, half crowded, shattering little; seeds straw-yellow, medium-sized, 7 to $7\frac{1}{2}$ mm. long, elliptical, much flattened; hilum light brown; germ yellow. Grown one season.

27501. From Shanghai, Kiangsu, China, 1909. Plants stout, erect, bushy; height 36 to 42 inches; very late; pubescence tawny; flowers purple; pods large, $2\frac{1}{2}$ to $2\frac{3}{4}$ inches long, compressed, scattered, shattering little; seeds olive-yellow, cloudy, large, $9\frac{1}{2}$ to 10 mm. long, elliptical, slightly flattened; hilum black; germ yellow. Grown one season.

THE BEST VARIETIES OF SOY BEANS.

It is difficult to determine the best soy-bean varieties out of those tested, not only on account of the very large number, but also owing to the divergent results reached at the various places where they have been grown. The soy bean seems to be peculiarly subject to fluctuations brought about by change of soil or change of climate. The differences in behavior of the same pedigreed seed in different places is often very striking, so much so that it is difficult to believe that it is the same variety. Whether these differences are due mainly to climate or to soil is difficult to determine, but in general the results indicate that both factors are potent. On this account it may very well be that the final conclusions reached by experimenters as to the best varieties will depend upon the place where the experiments have been conducted. The list of the best varieties here given is a tentative one based primarily upon the results at Arlington Experimental Farm, but those obtained in cooperation with various experiment stations have also been given due consideration. These matters should be given careful weight by all experimental agronomists, as otherwise it is conceivable that really valuable varieties may be overlooked or may be too hastily discarded.

Very early.—Ogemaw, 17258.

Early.—Early Brown, 25161; and Vireo, 22874.

Medium early.—Chernie, 18227; Auburn, 21079 A; Merko, 20412; Elton, 20406; Chestnut, 20405 B.

Medium.—Ito San, 17268; Medium Yellow, 17269; Tashing, 20854; Shingto, 21079; Swan, 22379; Brindle, 20407; Sedo, 23229; Lowrie, 22898 A.

Medium late.—Brooks, 16789; Flava, 16789 A; Cloud, 16790; Ebony, 17254; Haberlandt, 17271; Peking, 17852 B; Wilson, 19183; Taha, 21999; Austin, 17263.

Late.—Mammoth, 17280; Edward, 14953; Acme, 14954; Flat King, 17252; Tokyo, 17264; Hope, 17267; Hollybrook, 17278; Farnham, 22312.

Very late.—Barchet, 20798; Riceland, 20797.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Plant of the wild soy bean, No. 22428, grown in greenhouse. Note the very slender stems, vining habit, and small, scattered pods.

PLATE II. Fig. 1.—Wild soy bean from Soochow, China, No. 25138, grown at Arlington Experimental Farm, 1908. This variety could not be distinguished from No. 22428 when grown side by side. Note the slender vining stems and procumbent habit. Fig. 2.—Soy bean from Cawnpore, India, No. 24689, grown at Arlington Experimental Farm, 1909. This variety is very similar in habit to No. 25138, but is so late that it did not even bloom at Arlington.

PLATE III. Variety tests of soy beans at Arlington Experimental Farm. Note the erect, bushy habit, and differences in size and earliness.

PLATE IV. Seven varieties of soy beans, showing types of habit. No. 17852, Meyer; No. 17852 B, Peking; No. 17263, Austin; No. 18259, Pingsu; No. 22504, unnamed; No. 17278, Hollybrook; No. 17271, Haberlandt.

PLATE V. The same seven plants shown in Plate IV, after hanging in a dry room for six months. All have shattered badly but No. 17852 B, Peking.

PLATE VI. Pods of soy beans, showing range in size and shape. Most of the varieties have three seeds to the pod, two and four being only occasional numbers. (Natural size.)

PLATE VII. Soy-bean pods; No. 19985 L, hairy and smooth pods from one heterozygote individual; No. 18258 C and No. 17278, smooth pods from heterozygote plants; No. 22898 A, a variety with tumid pods; No. 19186 B, a variety with much-compressed pods.

PLATE VIII. The seeds shown on this plate are as follows, beginning with the upper row and extending from left to right, there being two seeds of each variety: Row 1, Nos. 22882, 17278, 23297 B, 24674, 24641; row 2, Nos. 17251, 24180, 17252, 25656, 22899 A; row 3, Nos. 25118, 23546, 17255, 24685, 16790 B, 25138; row 4, Nos. 25136, 23229, 20406 G, 22644 A, 19186 D; row 5, Nos. 20412, 22333, 17256, 20409, 22411 A, row 6, Nos. 24182, 17252 B, 17857, 17271 L, 17260; row 7, 21079 L, 23299, 20407, 17852, 20797 A; row 8, 19985 L, 21079 M, 18258 C, 19982 A, 19982 A.

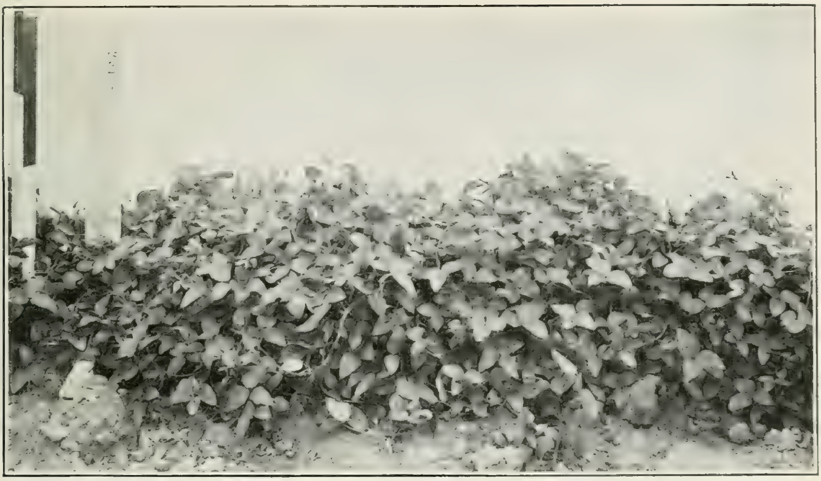


FIG. 1.—PLANTS OF A WILD SOY BEAN FROM SOOCHOW, CHINA, NO. 25138, GROWN AT THE ARLINGTON EXPERIMENTAL FARM, 1908.

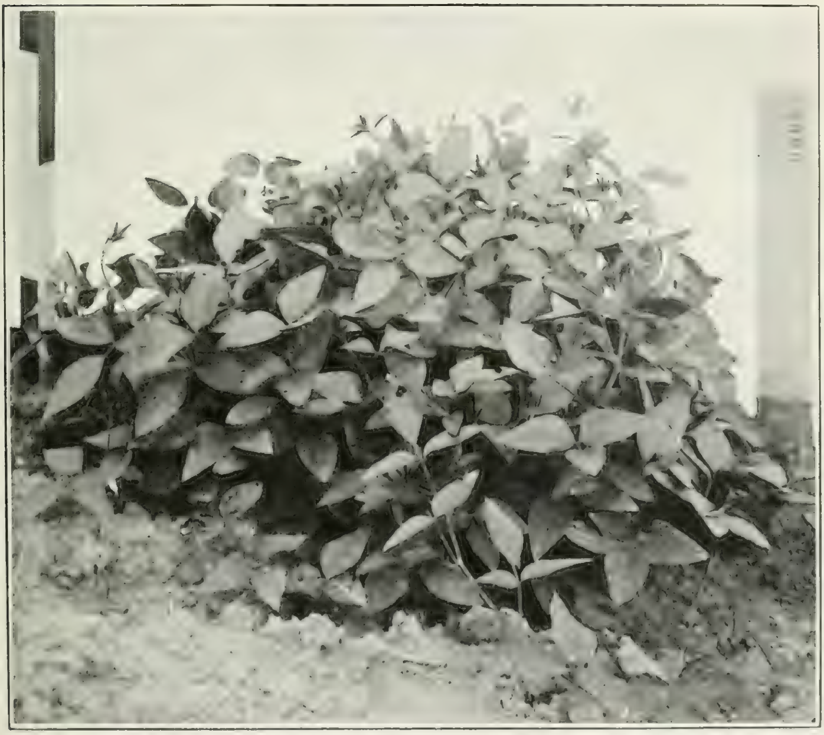
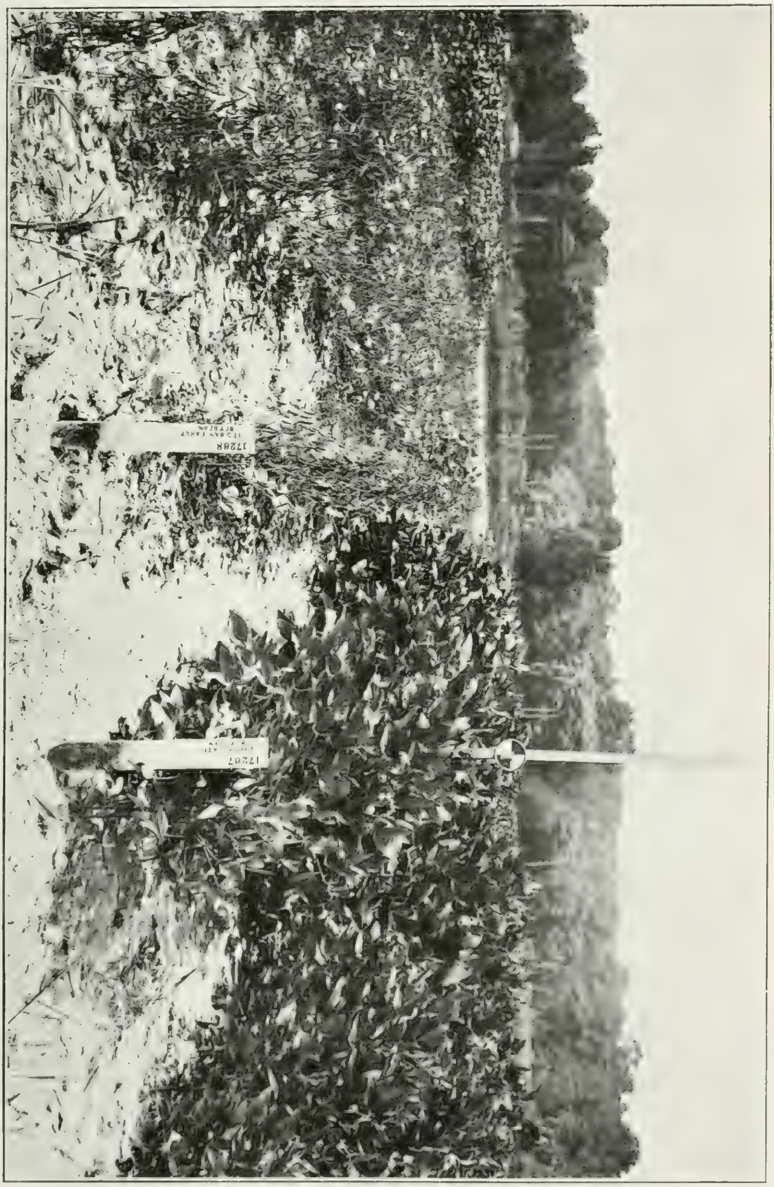
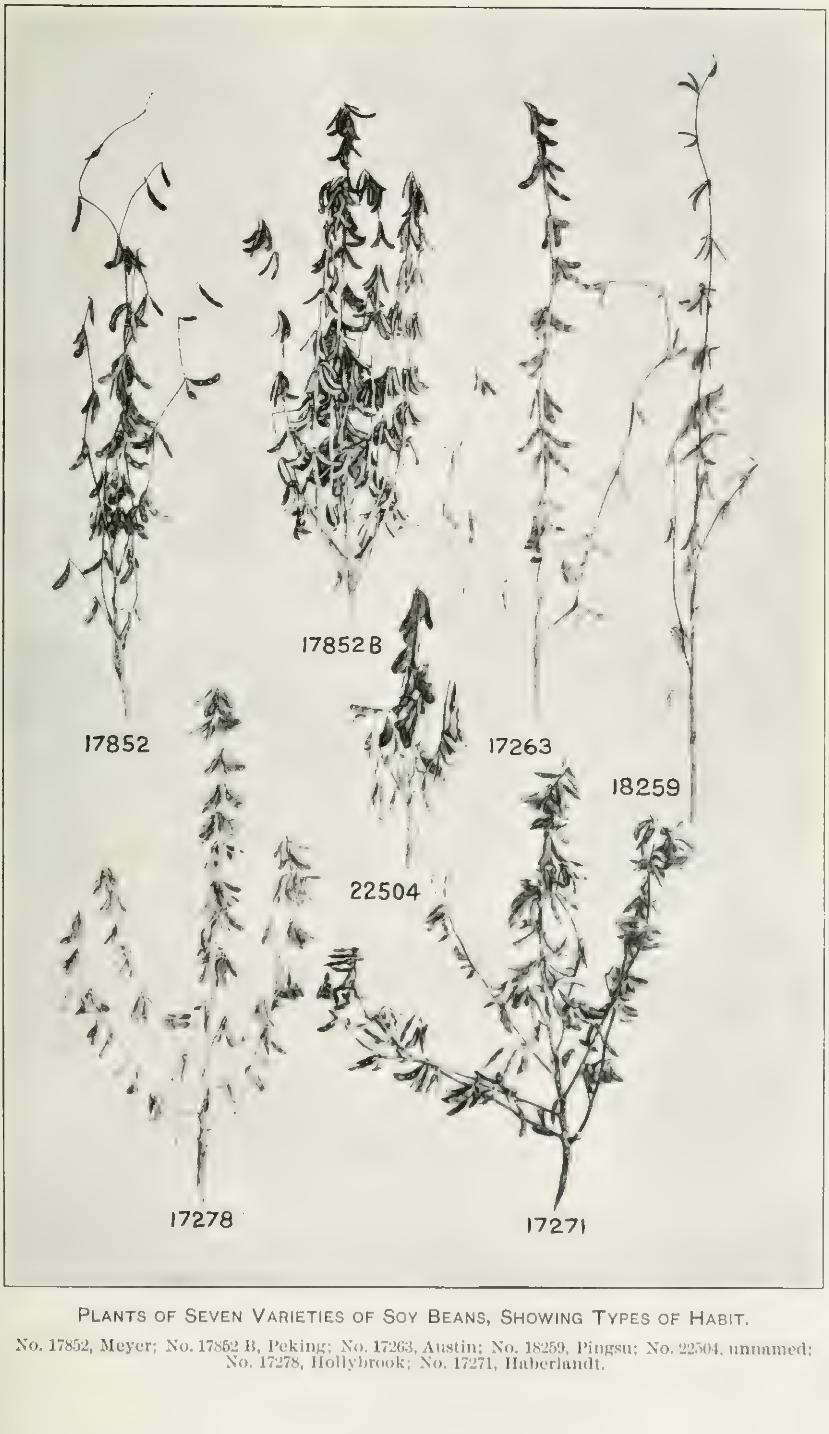


FIG. 2.—PLANTS OF A SOY BEAN FROM CAWNPORE, INDIA, NO. 24689.

PLATE III.

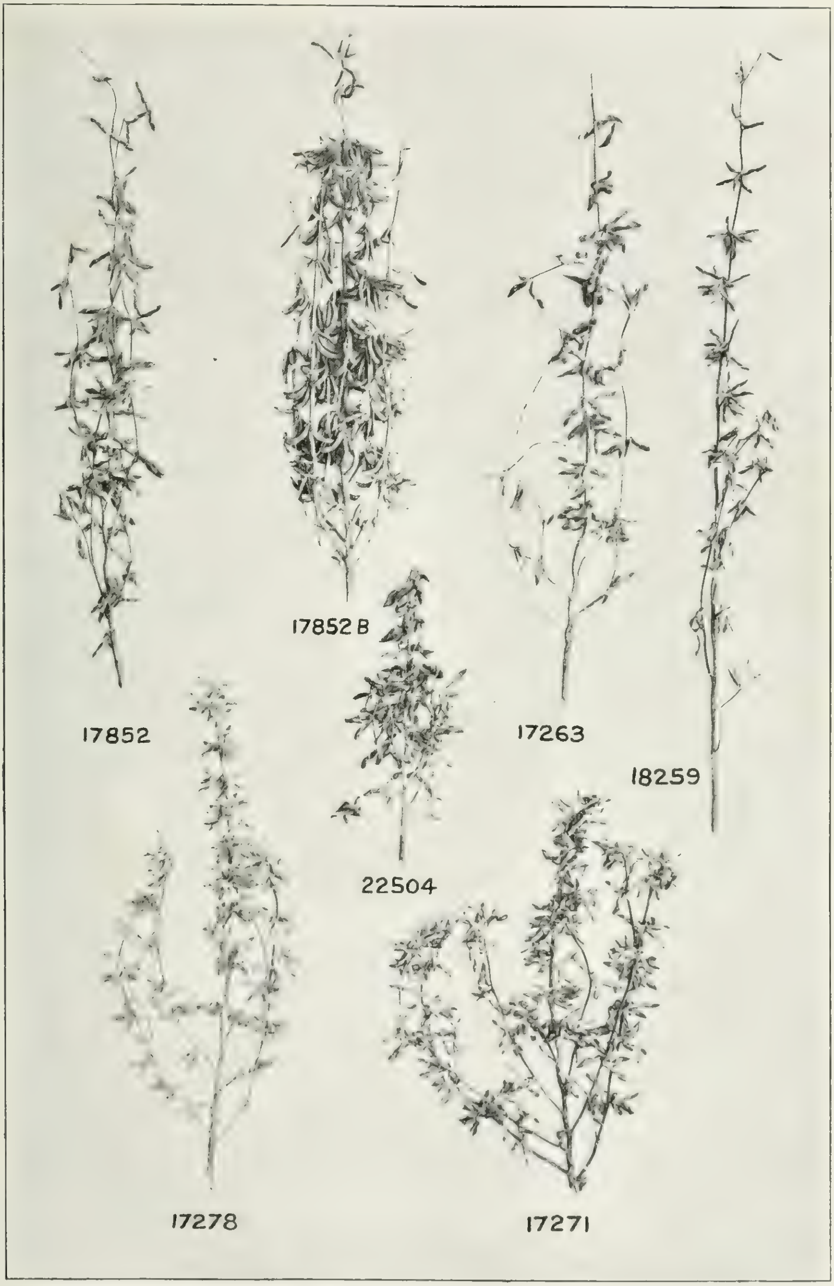


ROWS OF SOY BEANS GROWN IN THE VARIETY TESTS AT THE ARLINGTON EXPERIMENTAL FARM.


17852
17852 B
17263
18259
22504
17278
17271

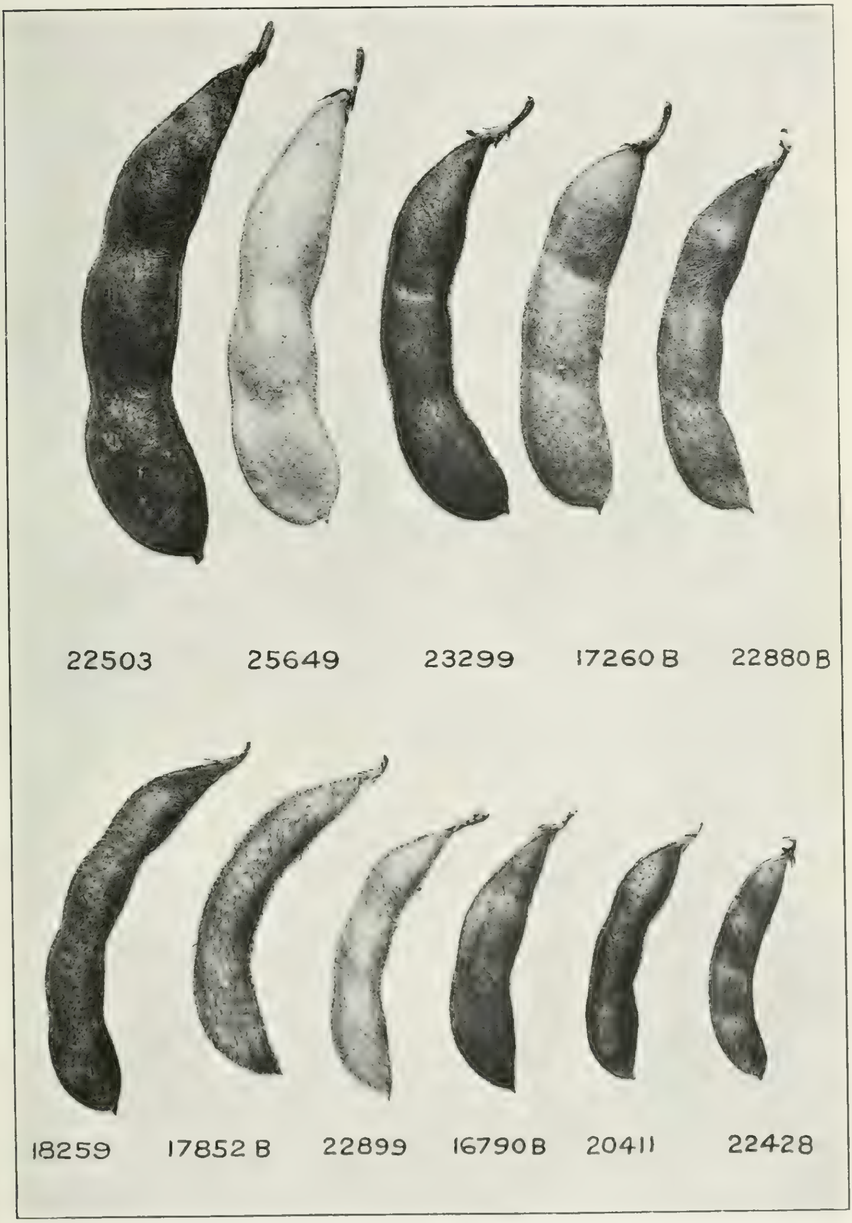
PLANTS OF SEVEN VARIETIES OF SOY BEANS, SHOWING TYPES OF HABIT.

No. 17852, Meyer; No. 17852 B, Peking; No. 17263, Austin; No. 18259, Pingsu; No. 22504, unnamed; No. 17278, Hollybrook; No. 17271, Haberlandt.


17852
17852 B
17263
18259
22504
17278
17271

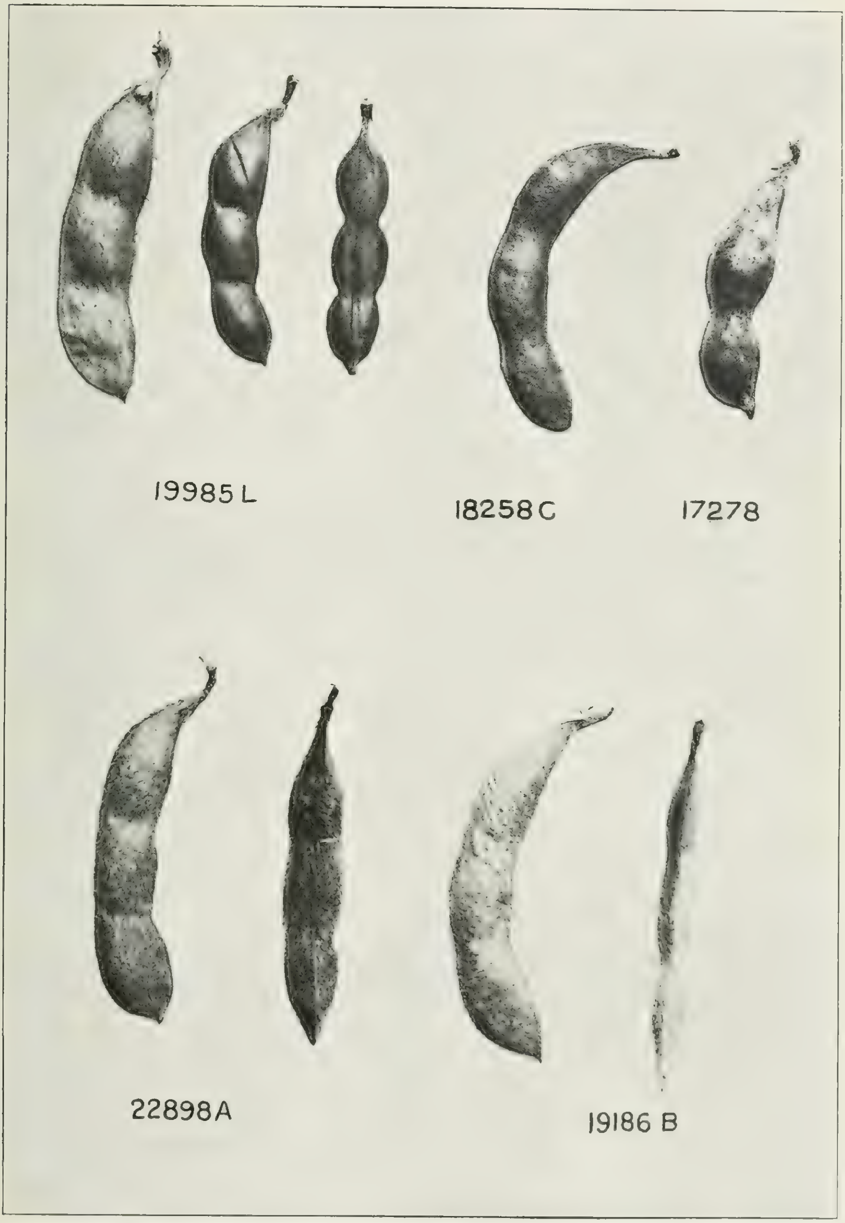
THE SAME PLANTS SHOWN IN PLATE IV AFTER HANGING IN A DRY ROOM FOR SIX MONTHS.

All have shattered badly but No. 17852 B, Peking.


22503
25649
23299
17260 B
22880 B
18259
17852 B
22899
16790 B
20411
22428

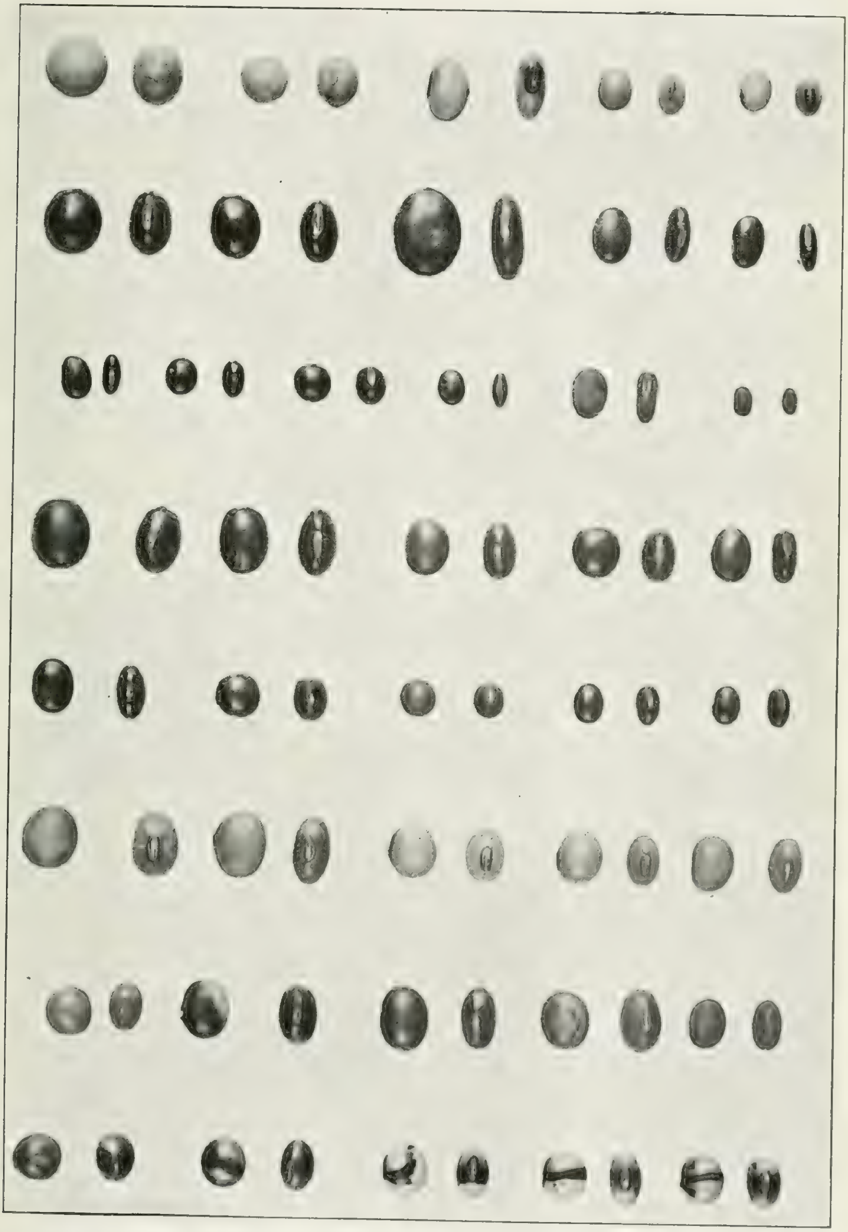
PODS OF SOY BEANS, SHOWING THE RANGE IN SIZE AND SHAPE.

(Natural size.)


19985 L
18258 C
17278
22898 A
19186 B

Pods of Soy Beans.

No. 19985 L, hairy and smooth pods from one heterozygote individual; No. 18258 C and No. 17278, smooth pods from heterozygote plants; No. 22898 A, a variety with tumid pods; No. 19186 B, a variety with much-compressed pods.



SEEDS OF 36 VARIETIES OF SOY BEANS, SHOWING VARIATION IN SIZE AND FORM.
The bottom row shows peculiar types of coloration that occur only on heterozygote plants.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 198.
B. T. GALLOWAY, *Chief of Bureau.*

DIMORPHIC BRANCHES IN TROPICAL CROP PLANTS:

COTTON, COFFEE, CACAO, THE CENTRAL AMERICAN RUBBER TREE, AND THE BANANA.

BY

O. F. COOK.

Issued January 14, 1911.

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SCIENTIFIC STAFF.

O. F. Cook, *Bionomist in Charge.*

G. N. Collins and F. L. Lewton, *Assistant Botanists.*
H. Pittier, *Special Field Agent.*
E. B. Boykin, J. H. Kinsler, Argyle McLachlan, and D. A. Saunders, *Special Agents.*
E. C. Ewing and R. M. Meade, *Assistants.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 2, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Dimorphic Branches in Tropical Crop Plants: Cotton, Coffee, Cacao, the Central American Rubber Tree, and the Banana," by Mr. O. F. Cook, Bionomist of this Bureau, and to recommend its publication as Bulletin No. 198 of the Bureau series. The paper shows that each plant produces two different kinds of branches, and points out numerous agricultural applications of these specialized habits of growth.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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DIMORPHIC BRANCHES IN TROPICAL CROP PLANTS: COTTON, COFFEE, CACAO, THE CENTRAL AMERICAN RUBBER TREE, AND THE BANANA.

INTRODUCTION.

It has been known for a long time that some species of plants have two or more forms of branches, but such specializations have been looked upon as botanical curiosities rather than as having practical significance in agriculture. Several of the most important economic species of the Tropics have now been found to have two or more different and distinct kinds of branches regularly present on every normal plant. These differences in the formation of the branches are worthy of scientific study and have definite relations to agricultural problems.

The specializations of the branches of the tropical crop plants are not mere inequalities of position and development like those that commonly appear among the trees and shrubs of the temperate regions. The differences do not arise merely from favorable or unfavorable positions on the plant that might affect the supply of food or the exposure to sunlight. The two kinds of branches are in most cases so definitely different that they do not replace or serve as substitutes for each other. The differences of the branches have sometimes been recognized by individual planters of coffee or cacao, but they have not received the study that the facts would warrant, either in their scientific aspects or in relation to practical agricultural applications.

As the best means of describing the nature and extent of the diversity of branches which exists in several of the more important tropical crop plants, it seems desirable to bring together in one report the facts of this kind which have been observed. The cultural significance of some of them is at once obvious and will show the desirability of further study in this class of phenomena. That much more information of this kind remains to be discovered seems strongly to be indicated by the fact that a definite diversity of branches has been found in all of the principal tropical crop plants to which attention has been directed with this idea in mind.

STRUCTURAL SIGNIFICANCE OF DIMORPHIC BRANCHES.

In attempting to understand the dimorphism of branches it is desirable to consider the nature of the structural units that compose the bodies of the plants. For some of the purposes of scientific study the individual cells or the tissues formed by the cells of one kind can be considered as units of structure. But many forms of plant and animal life also show structural units of a higher degree, such as the many similar joints or segments that compose the bodies of the worms and centipedes and the internodes of higher plants. Each joint is highly complex in itself, with a complete system of tissues and organs. The word " metamer " is used as a general term to apply to these complex units of organic structure. In some of the lower forms of animal life each metamer is capable of an independent existence, just as in some plants each joint of the stem or the rootstock, if planted as a cutting, will grow into a new individual. In a similar way each seedling represents a single metamer, able to produce others.

Two general groups of metamers may be recognized in plants—those that build up the vegetative parts of the plant and those that take part in the formation of the flowers and fruit. A vegetative metamer consists of a joint or section of the stem, together with a root or roots, and one or more leaves, as well as the hairs, scales, and other smaller appendages that belong to the joint, the root, or the leaf.

The floral or reproductive metamers of plants are generally smaller than the vegetative metamers. The part that corresponds to the joint or section of the stem of a vegetative internode is extremely short, while the part that corresponds to the leaf takes the form of a sepal, stamen, or pistil.

A plant as a whole represents a collective individual—a social organization, as it were—of the different kinds of subordinate metameric individuals, some devoted to vegetative purposes and some to reproduction. Botanical writers have often referred to the floral organs as transformed leaves, but it is quite as reasonable to suppose that the leaves represent floral or reproductive organs that have assumed vegetative functions.[a]

The stamens and pistils of the primitive types of plants are more nearly like those of the advanced types than are the vegetative metamers, showing that evolution has tended more toward the specialization of the vegetative parts. Dimorphic branches represent a somewhat advanced stage of vegetative specialization. A plant with dimorphic branches has two kinds of vegetative metamers, in addition to the various kinds of floral or reproductive metamers. In the cotton plant, for example, seven principal kinds of metamers might be enumerated: The two kinds that compose the two types of branches, the two kinds whose specialized leaves form the involucre and the calyx, and the metamers of the corolla, the stamens, and the pistils. Some plants, such as Broussonetia, have two kinds of vegetative metamers alternating in the same stem, each alternate internode having only a small leaf.[a]

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[a] Cook, O. F. Origin and Evolution of Angiosperms through Apospory. Proceedings, Washington Academy of Sciences, vol. 9, 1907, pp. 150–178

The diversity of the metamers does not end with the recognition of the different types, for the individual metamers of the various groups are often as distinctly different among themselves as the plants they compose, or even more so. If it be considered that a plant is an aggregate or colony of metamers, it follows that causes of differences between plants are to be sought in the structure or behavior of the component metamers. Plants with dimorphic branches not only have two kinds of vegetative metamers, but have them arranged in separate series. The variations of the higher plants are much more readily appreciable than the variations of the higher animals, because the same character is repeated in the large number of internode individuals that compose the bodies of plants.

The individuality of the internodes and the significance of this fact in the developmental history of plants were appreciated over a century ago by Goethe, the great German naturalist and poet. In his poem on "The Evolution of Plants," the series of changes in the forms of the metamers is traced from the seedling, the process of plant growth being used as an illustration of the general idea of evolution from simple forms of life to more complex.

> Yet it appears very simple, when first we can see the new structure,
> This in the world of the plants is ever the state of the child.
> Growth is continued at once, one shoot coming forth from another,
> Nodes upon nodes towering up, all repeating the form of the first.
> Still they are not quite the same; in manifold ways they are varied,
> Each of the leaves, as you see, develops beyond the preceding,
> Larger, and sharper in margin, as well as more deeply divided.

Not only the differences of the vegetative internodes, but those of the internodes that are modified as flower stalks and floral organs were recognized, as well as the sexual differentiation of the stamens and pistils, though the poem was published in 1790, three years before the announcement of Sprengel's discovery of the fertilization of flowers. Comparison of the series of gradually modified internodes in the individual plant with the successive links of the chain of organic development led Goethe to the view that each plant is an evidence of a general law of evolution.

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[a] Other examples of anisophylly have been described by several botanical writers. See Wiesner, J., Studien ueber die Anisophyllie tropischer Gewaechse, Sitzungsberichte der Mathematisch-Naturwissenschaftlichen Classe, Kaiserliche Akademie der Wissenschaften, Vienna, vol. 103, 1894, p. 625.

> Every plant will declare it, the law of the endless creation,
> Every flower will repeat it, louder and louder the voice.

SIMILARITY OF DIMORPHIC BRANCHES TO ALTERNATING GENERATIONS.

Darwin also recognized the individuality of the internodes of plants, though apparently without attaching an evolutionary significance to the fact, no reference being made to it in "The Origin of Species." Attention has been called by Mr. Argyle McLachlan to an interesting paragraph in another work, in which Darwin draws a comparison between the leaf buds of plants and the individual animals that build up the branching colonies of zoophytes:

> The examination of these compound animals was always very interesting to me. What can be more remarkable than to see a plant-like body producing an egg, capable of swimming about and of choosing a proper place to adhere to, which then sprouts into branches, each crowded with innumerable distinct animals, often of complicated organizations. The branches, moreover, as we have just seen, sometimes possess organs capable of movement and independent of the polypi. Surprising as this union of separate individuals in a common stock must always appear, every tree displays the same fact, for buds must be considered as individual plants. It is, however, natural to consider a polypus, furnished with a mouth, intestines, and other organs, as a distinct individual, whereas the individuality of a leaf bud is not easily realized; so that the union of separate individuals in a common body is more striking in a coralline than in a tree. Our conception of a compound animal, where in some respects the individuality of each is not completed, may be aided by reflecting on the production of two distinct creatures, by bisecting a single one with a knife, or where nature herself performs the task of bisection. We may consider the polypi in a zoophyte, or the buds in a tree, as cases where the division of the individual has not been completely effected. Certainly in the case of trees, and judging from analogy in that of corallines, the individuals propagated by buds seem more intimately related to each other than eggs or seeds are to their parents. It seems now pretty well established that plants propagated by buds all partake of a common duration of life, and it is familiar to every one what singular and numerous peculiarities are transmitted with certainty by buds, layers, and grafts, which by seminal propagation never or only casually reappear.[a]

It is plain from this passage that Darwin considered the internodal structure of plants as a method of vegetative propagation of new individuals rather than as an example of successive stages of evolutionary progress. This becomes the more evident from his comparison of the results of vegetative propagation with those obtained by sexual reproduction. The general tendency to uniformity among vegetative individuals lends greater significance to differences that regularly appear among vegetative internodes of the same plant. Dimorphic branches and similar specializations show that change of characters in vegetative internodes is a definite phenomenon in the development of plants, like changes that take place during the development of many animals. Much evolutionary importance has been attached by zoologists to the recapitulation of ancestral characters in embryos, as well as to metamorphosis and alternation of generations. All of these phenomena find their parallels among plants, though botanists have given them relatively little attention.

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[a] Darwin, Charles. Journal of Researches, end of chapter 9.

The evolutionary development of the various degrees of specialization of the branches of such a plant as the cotton becomes more comprehensible if we compare it with the stages through which a simple herb would naturally pass in attaining the stature and habit of a branching shrub or tree. Many small herbs bear single terminal flowers, but in plants that have increased in size and complexity terminal flowers are replaced by axillary flowers or flower clusters, and these tend in turn to grow out into branches, able to subdivide still further and bear larger and larger numbers of flowers.

In the cotton plant the primary branches have now become as sterile as the main stem, and the extra-axillary branches that normally bear the fruit also have the power of changing over into sterile limbs, the production of fruit being deferred to a later generation of branches to enable the plant to construct a larger vegetative framework.

The main stem and the one or more series of vegetative branches which intervene between the germination of the seed and the formation of another flower correspond to several generations of the vegetative parts of a simple herb and might also be compared to the vegetative generations of the plant lice and other lower animals that are able to propagate for several generations by simple vegetative subdivision, instead of requiring sexual reproduction for each generation of new individuals, as among the higher animals. The relations between the sterile and the fertile branches of cotton and of other plants that have dimorphic branches afford a rather close parallel to the original examples of the phenomenon of alternation of generations, though they are not comparable to the changes that occur in the life histories of the liverworts, mosses, and ferns which botanical text-books commonly describe as alternation of generations.[a]

A shrub or tree may be thought of as a colony or complex of many individual branches each corresponding to a separate plant in a species of smaller shrubs or herbs. Dimorphism of branches means that there are two kinds of these branch individuals that follow each other in definitely alternating sequences. The seeds of the cotton, coffee, and many other species do not grow at first into plants similar to the branches which produced the seeds. The seedlings at first develop upright sterile stems and a series of vegetative branches. Another type of branches is formed for the production of flowers and fruit, and then there may be no return to the condition of the upright main stem and the purely vegetative limbs except by way of the seed and seedlings.

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[a] Cook, O. F., and Swingle, W. T. Evolution of Cellular Structures. Bulletin 81, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905.

In some plants the formation of different kinds of vegetative internodes is more specialized in relation to time, the whole plant going over from one habit of growth or form of foliage to another. In the eucalyptus and in many coniferous trees related to the juniper there is a juvenile form of foliage altogether different from that of the adult trees. This phenomenon is not to be confused with the simpler dimorphism of branches shown in the tropical crop plants, though some of the Coniferæ have this as well as the other. Cuttings of lateral branches, not being able to replace the main axis, do not reproduce the form of the parent tree. Some of the Coniferæ produce a juvenile type of foliage only in exceptional cases of bud reversion, which may even be confined to buds forced from the axils of the cotyledons, as explained by Beissner and Beyerinck.[a]

DIFFERENT TYPES OF DIMORPHIC BRANCHES.

It is easier to describe and compare the dimorphic forms of branches in the several species of cultivated plants if we consider in advance a general difference of function. Some branches have the same form and functions as the axis or main stem of the plant, while others are more or less restricted to the bearing of fruit or to other special purposes. The specializations of the branches show various directions and degrees in different species and varieties of plants, but in each case it is possible to distinguish between branches that are more similar to the main trunk and those that are less similar.

In the present report the word " limb " is used as the general name for branches that are unspecialized or that are specialized for vegetative functions instead of for fruiting. The limbs continue the growth and share the functions of the trunk or main stem of the plant.[b] Limbs may have vegetative functions only and may be unable to bear flowers or fruit. Branches that bear fruit may be correspondingly restricted on the vegetative side. Different species and varieties of plants are so unlike that no general principle of classification can be applied except that of distinguishing between the different forms of specialization.

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[a] Beissner, L. Ueber Jugendformen von Pflanzen, speciell von Coniferen, Bericht über die Verhandlungen der deutschen botanischen Gesellschaft, vol. 6, 1888, p. lxxxiii. Beyerinck, M. W. Beissner's Untersuchungen üeber der Retinisporafrage, Botanische Zeitung, vol. 48, 1890, p. 518.

[b] In the diagrams that illustrate the habits of branching in this report the vegetative limbs are drawn in solid lines like the main stem, while the fruiting branches are indicated by broken lines. (See figs. 1–7.)

The most useful distinction between limbs and other forms of branches relates to differences of function rather than to the structure or positions of the parts. In the cotton plant, for example, the axillary branches function as limbs, while in the Central American rubber tree they are definitely specialized for fruiting and do not become permanent parts of the tree. They die and drop off after they have borne two or three crops of fruit.

The branches that arise from extra-axillary buds also have their functions reversed in the two cases. In the rubber tree the extra-axillary buds produce limbs but no fruiting branches, while in the cotton plant all the fertile branches arise from extra-axillary buds.

DIMORPHIC BRANCHES OF THE COTTON PLANT.

Though the dimorphism of the branches of the cotton plant is not an extreme case, it may be better to use it as the first example before considering the other tropical plants that are less known in the United States. The differences are more striking in some of the tropical plants, but are no more significant in their agricultural bearings. The distinctions between the two kinds of branches of the cotton plant depend upon position and function rather than upon any very conspicuous differences of form or structure. This may explain why the dimorphism of the branches has continued to be overlooked in so familiar a plant as the cotton, although the difference between ordinary short fruiting branches and large basal branches or "wood limbs" is obvious at a glance and is familiar to all planters.[a]

The cotton plant, as represented by the Upland varieties in general cultivation in the Southern States, consists of a central axis or "stalk" bearing a leaf at the end of each joint or internode. Branches that arise from the axils of the leaves do not normally bear fruit, but behave like divisions of the main stalk. A fertile branch arises at one side, right or left, of an axillary branch or an undeveloped axillary bud which may give rise to an axillary branch late in the season. The position is usually constant throughout in the same stalk, so that the plants can be distinguished as right-handed or left-handed with reference to the position in which their fruiting branches are borne along the main stalk.

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[a] For a brief statement regarding dimorphism of branches in cotton, see "Weevil-Resisting Adaptations of the Cotton Plant," Bulletin 88, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1906, pp. 19–20. See also "A Study of Diversity in Egyptian Cotton," Bulletin 156, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 28–30.

On the fruiting branches this regularity in the position of the flowers is not so obvious, for the joints are twisted to bring all the leaves to the sides and all the flower buds on top. The flower buds appear between the bases of the stipules, sometimes nearer the right-hand stipule, sometimes nearer the left. The stipule that is close to the base of the flower stalk is usually larger than the other.

Antidromy, as the condition of right and left handedness of plants has been called, consists in the fact that the stems of the different individual plants reverse the direction of the spirals in which the leaves and branches are arranged. On some cotton plants the extra-axillary branches occur on the right side of the axillary branches; in other individuals on the left side. If a stalk on which the extra-axillary buds appear to the right of the axillary buds be considered right-handed, the turn of the spiral will pass to the right in going by the shortest route from any given branch to the one above. Thus it appears that the extra-axillary bud is always above the axillary, in the sense that it is farther up the spiral.

In all the different species and varieties of cotton thus far examined right-handed and left-handed stalks seem to be about equally numerous. As the Guatemalan types in which the branch dimorphism was first studied had never undergone close selection, the question was raised whether among the carefully bred American varieties there might not be specializations toward one direction of the spiral. No indication of this was found in a large series of varieties studied by Mr. F. J. Tyler at Waco, Tex. Seeds from the same boll were also found to give about equal proportions of right-handed and left-handed seedlings. The possibility remained that the direction of the spiral may be determined in advance by the positions in which the seeds develop on the placenta. To test this theory seeds from two rows of the placenta were planted separately, but gave right and left handed plants without reference to the position on the placenta. The manner in which this diversity arises remains unexplained.

The axillary buds have been found in all the types and varieties of cotton thus far observed, but they are often very small and dormant. They may all remain undeveloped unless the plant is cut back or severely checked by unfavorable conditions. In many kinds of cotton both types of branches are commonly to be found on the same plant.

The difference between the two kinds of branches was first appreciated in Guatemala in connection with the indigenous Kekchi cotton. The lower joints of the main stem of the Kekchi cotton usually produce two branches, one a fertile branch with flowers and fruit, the other a sterile limb with leaves only. It was noticed also that the branches that bear the flowers arise in the same position as the flowers themselves—not in the axils of the leaves, but at the side of the axillary bud.

The axillary branches of cotton function normally as equivalents of the main stem in the sense that they do not bear any flowers or fruits except in the indirect way of producing other branches of the fertile sort from extra-axillary buds. Fertile branches borne by the main stem of a cotton plant may be called primary fruiting branches; those that come from limbs may be called secondary fruiting branches. Normal fruiting branches of both kinds bear a flower bud at each node. Secondary limbs may be produced from primary limbs, or even from axillary buds of the fruiting branches, especially if a plant has been injured or pruned or suddenly forced into renewed growth late in the season. Only in rare and abnormal cases is a flower borne directly on a branch that arises from an axillary bud.

It is the normal habit of some varieties to develop vegetative limbs from axillary buds along with the fruiting branches that come from the extra-axillary buds, as in the Kekchi cotton of Guatemala. Some varieties do not have true axillary branches, but develop limbs from the extra-axillary buds of the main stem, the production of flowers being deferred until fertile branches can be produced on the limbs. This is sometimes the case with the Pachon cotton of western Guatemala and with the Rabinal cotton of the central plateau region. In an experiment with the Pachon cotton at Lanham, Md., no axillary limbs were produced, each node bearing only an extra-axillary limb. In another experiment at Trece Aguas, Alta Vera Paz, Guatemala, the Pachon cotton showed nearly the normal habit of the Upland type of cotton, bearing most of its crop directly on fertile primary branches, sending out small primary limbs only in the latter part of the season.

In the Old World cottons (*Gossypium herbaceum*) and the Sea Island cottons it is not usual for the plants to develop true axillary limbs to functional size. If the other branches are injured or stunted, the axillary limbs may push out a few leaves.

In the Egyptian cotton, also, there is a very general tendency to develop vegetative limbs as well as the fertile branches from extra-axillary buds. The axillary buds usually remain dormant unless an injury or other abnormal condition forces them into growth. At the base of the main stalk it is often difficult to see that the limbs come from extra-axillary buds, but a little farther up it becomes obvious that both the limbs and the fruiting branches have extra-axillary positions on the same side of the axillary bud, with much regularity. Finally, some varieties of Upland cotton may not form any vegetative branches, though extra-axillary limbs and even axillary limbs may be formed by the same varieties when grown under conditions that favor a large development of the vegetative parts.

In the so-called "cluster" cottons it often happens that one or more buds, or bolls, appear to be borne on short axillary branches, but careful examination will usually show that the fruit does not come directly from the axillary branch itself, but belongs to a very short fertile branch arising from the axillary. In the Egyptian cotton a short fertile branch is often pushed out from one side of the dormant bud that represents an undeveloped axillary branch. Sometimes the bud that represents an undeveloped axillary branch is carried up a little on the base of the extra-axillary branch. After this has occurred, a branch that arises from the axillary bud appears to be borne by the extra-axillary branch rather than by the main stem of the plant. This impression may be strengthened still further if the axillary bud or the fruiting branch to which it sometimes gives rise be changed into flower bud, as in the cluster cottons that show an abnormal propensity toward fruit production. Sometimes the normal extra-axillary fruiting branch is also replaced by a single flower bud, so that three flower buds may appear to come from each of the nodes of the main stem instead of the more normal complement of a limb and a fertile branch.

In varieties of cotton that are not inclined to produce true axillary limbs, the extra-axillary branches usually assume the functions of limbs; that is, they produce flowering branches instead of bearing the flowers themselves. A true axillary limb seldom stands alone on the main stem, but is almost invariably accompanied or preceded by a fertile branch. The insertion of a limb and a branch close together, at the same node, makes it easy to ascertain whether true primary limbs are present or limbs that represent fruiting branches transformed for vegetative purposes.

The leaves of the vegetative limbs and those of the main stem are larger and have relatively longer petioles than those of the fruiting branches. Another definite difference between the leaves of the main stem and those of the fertile branches has been noticed by Mr. Rowland M. Meade in the Triumph variety of Upland cotton. The leaves of the main stem have nectaries on three of the veins, while those of the fertile branches have only the one nectary, on the back of the midrib. When the fruiting branches are shortened, as often happens in the Egyptian cotton, the petioles of their leaves are also greatly reduced in length, a step toward the still more distinctly abnormal condition where the leaves of the shortened fertile branches begin to show some of the characteristics of the involucral bracts.

In types of cotton that have a normal development of branches an axillary bud yields only a sterile vegetative branch or limb. From extra-axillary buds three things may come: (1) Flowers, (2) fertile branches bearing a series of flower buds, one at each node, and (3) extra-axillary limbs having the position of fertile branches but sharing the form and function of the axillary limbs.

VARIOUS FORMS OF FRUITING BRANCHES.

As the fruiting branches represent a specialized feature of the cotton plant, it is not surprising that different stages of specialization are found in the fruiting branches of the various species and varieties of cotton. Though the general distinctions between the vegetative limbs and the fertile branches apply to all forms of cotton thus far examined, definite differences often appear between the fruiting branches of different varieties and even among the individual members of the same variety; and since these differences in the methods of producing the fruit are of direct agricultural importance, it is worth while to understand them in detail.

In a general botanical sense it might be said that the fruiting branches of all kinds are intermediate between the vegetative limbs and the flowers, for botanists consider that each flower of a plant represents a shortened branch. The range of specialization of fertile branches lies, therefore, between the limb and the flower. The fertile branches of some cottons are long and leafy, much like the vegetative limbs, while in others they may be so much shortened as to appear merely a part of the flower stalk. In the great majority of cases the fertile branches are definitely unlike either of the extremes, but the range of forms is completely covered if the whole series is considered.

A comparison of the branches of the Egyptian cotton with those of the Kekchi cotton or with our United States Upland varieties may serve as an illustration of the different degrees of specialization found in the branches in different types of cotton. In the Egyptian cotton the basal joints of the fruiting branches are longer than in the Upland, while on the vegetative branches the basal joints are shorter than on the corresponding branches of the Upland. In other words, the differences between the basal joints of the two kinds of branches are much greater in the Egyptian cotton than in the Upland series. The tendency for the basal joint of the fruiting branches to be longer than the others is very general, and likewise for the basal joints of vegetative branches to be shorter, but in the Egyptian cotton the contrast is more accentuated than usual.

The Hindi cotton that figures in literature as a contamination of the high-grade Egyptian stocks shows the slightest differentiation of the fruiting branches. These branches have a curious zigzag form that readily distinguishes them from the straight vegetative limbs, but they may retain the nearly upright position of the limbs and do not appear to have lost any of the vegetative functions. In such cases the flower buds are usually aborted at an early stage, though mature bolls are sometimes found on branches that remain more upright and limblike than those in Upland or Egyptian varieties.

The other extremes of differentiation in the direction of the shortening of the fruiting branches are found in great variety among the so-called "cluster" cottons. The simplest form of clustering is represented by a mere shortening of the joints of the fruiting branches, which brings the flowers and bolls closer together than in normal long-branched varieties. More pronounced clustering leads to denser groupings of bolls by the development of additional flowers on short branches from the axils of the leaves of the fruiting branches. In its most extreme form the clustering has the effect of reducing the number of bolls. The leaf buds that normally continue the growth of the branches are sometimes replaced by flower buds, or adjacent leaf buds may be aborted and fall off, so that the branch soon ends with a flower or a boll and no more joints can be added.

It usually appears that the cluster habit is merely a form of specialization of the fruiting branches, for the vegetative limbs and axillary branches are usually not affected at all by the cluster tendency. In other cases the axillary buds of the vegetative branches, as well as the terminal buds, may appear to be replaced by flower buds, though it is usually found, on closer examination, that the flower bud is borne on a short fertile branch that rises from an otherwise abortive axillary branch.

Finally, it sometimes happens, as in the Triumph variety of Upland cotton, that two forms of fruiting branches are regularly produced. The normal condition with the Triumph cotton is to have several of the lower fruiting branches very short and determinate, so that sometimes this variety is erroneously described as a cluster type.

STERILITY OF INTERMEDIATE FORMS OF BRANCHES.

Botanists are familiar with the fact that changes and substitution of form often occur among the floral organs of plants. The most familiar change of this kind is in the so-called doubling of flowers, meaning the addition of a larger number of petals to the corolla. In many cases the number of stamens decreases as the petals become more numerous, and many double flowers are completely sterile, both the stamens and pistils being transformed into petal-like organs.

Such changes are occasionally found in the flowers of the cotton plant, as when additional petals are inserted on the staminal tube. Sometimes these additional petals are very small, as though individual stamens had been changed into petals. More serious modifications appear when petals of nearly normal size are inserted on the base of the staminal tube, which is then subdivided into five separate columns alternating with the supernumerary petals. Pistils are sometimes transformed into supernumerary petals, though the change is seldom complete. Some of the pistils usually remain unmodified, but the boll is deformed and seldom develops to maturity.

In view of the occurrence of intermediate conditions between the parts that are so profoundly different as the stamens and pistils, it would naturally be expected that intermediate stages would also occur between the two forms of branches, in spite of the fact that dimorphism represents the normal condition. Intermediate forms of branches do occur, and, like the intermediate forms of the floral organs, they are usually sterile. Not only do most of their flower buds abort, but the branches themselves commonly fail to reach full development. They often wither and fall off after producing one or two internodes.

If such branches occurred without regularity on the plant, it might be difficult to determine the nature of the abnormality, but they have evident relations to particular varieties and to definite positions on the plants. In following the branching habits of the Egyptian cotton through the season of 1909, Mr. McLachlan noticed the curious fact that an interval of rudimentary or abortive branches usually occurs on the main stem of the plant, consisting of two or three internodes above the last of the sterile vegetative branches and below the first normally developed fruiting branch. Even on large plants that bear limbs 4 feet or more in length, with 30 internodes and upward, and fruiting branches nearly 2 feet in length, composed of twelve internodes, the intervening nodes are either quite vacant or have branches only a few inches long, usually with only one internode, very seldom with more than two or three. Sometimes there is a more gradual transition from these small branches to those of normal length, but there is a strong tendency to abortion of the flower buds on all of the shortened lower branches of the fertile form.

As already suggested, the frequency of abnormal branches in the Egyptian cotton may be connected with the contamination of the Egyptian stocks with the so-called Hindi cotton, a type related in some respects to our United States Upland cotton, but widely differing in others. Though the Hindi cotton has the two distinct forms of branches, they appear less different than in any other variety included in the experiment. It seems to be the regular habit of Hindi cotton to shed a large proportion of its flowers in the very young stages and then to develop the vegetative functions of these barren fertile branches which not only grow to large size, but often produce branches of their own from axillary buds. In view of these habits of the Hindi cotton, it does not appear improbable that the frequent tendency of the Egyptian plants toward abnormal, intermediate forms of branches is caused, or at least intensified, by admixture with the Hindi type. In any case the characters of the branches must be taken into account as one of the standards of selection in the Egyptian cotton, as well as in Upland varieties.

In addition to the relatively small and late development of the fruiting branches on vigorous, overgrown Egyptian plants a very large proportion of the flower buds are aborted and fall off. Many of them are dropped while still very small and even microscopic in size. This abortion of the buds appears to have a definite relation to the habits of branching of the plants. If the fruiting branches are of a normal, slender, and horizontal form, the chances of the buds being retained are very much greater. If, on the other hand, the fruiting branches become more robust and take an oblique or upright direction and thus resemble the vegetative branches or limbs, the buds almost invariable fall off while still very young. Only the scars of the fallen buds may remain as a distinction between the fertile and sterile branches, as in the Hindi cotton. On different plants and even on different branches of the same plant, the buds attain different sizes before they abort and fall off, and these different sizes of the buds may be considered as marking intermediate stages between the normal fertile branches which retain their fruit and the normally sterile vegetative branches which produce no trace of flowering buds.

The practical point is that these intermediate conditions and forms of the branches, even when they bear large numbers of buds, produce very little fruit, often none at all. The failure of a plant to maintain the normal specialization of the two forms of branches is an undesirable character from the standpoint of acclimatization and breeding. There is not only a tendency on the part of the newly imported plants to increase the number of sterile vegetative branches at the expense of the fertile, but a tendency for the remainder of the fertile branches to become abnormal.

While it is possible for a very large and vigorous plant to produce a good crop of cotton with a sufficiently long season, there can be no regular assurance of large yields unless the plants begin to bear early in the season. The plants must begin to produce fertile branches early in the season and numerous buds on each branch. It is not to be expected that all of the buds of a fertile plant will set bolls, or that all the bolls will reach maturity, but this only makes it the more important that the plants shall be able to produce enough flower buds to take advantage of all opportunities for the setting of a large crop. The tendency of the Egyptian cotton to grow larger vegetative branches and smaller fruiting branches than the Upland cotton is responsible for differences in yield and earliness between the two types.

In Egypt and in the cooler parts of the United States the Egyptian cotton produces small, early plants with much the same habit of growth as the Upland cotton. The more fertile soils and the greater heat of the spring months in the Southwestern States induce a much more luxuriant growth, especially in the Egyptian cotton. The plants not only shoot up to a very large size, but put forth many vegetative branches from the base of the stalk before any fertile branches are formed.

INTERMEDIATES BETWEEN FERTILE BRANCHES AND FLOWERS.

Farther toward the top of the plants another intermediate condition of the branches is frequently found, especially in the Egyptian cotton. The fertile branches become abnormal by approximation to flower buds. The leaf bud that would continue the growth of a normal fruiting branch either becomes abortive or appears to be directly transformed into a flower bud. A further evidence of the abnormality of these branches is found in the fact that their leaves are usually different from those of normal fruiting branches and tend to take on the form of the floral bracts. The first and most frequent manifestations of this tendency are found in the shortening of the petiole or stem of the leaf and the enlargement of the stipules—the small, pointed, leaf-like structures at the base of the petiole. (See Pl. I.)

On the normal fruiting branches the stipules are always shorter than those of the main stem or vegetative limbs, remaining narrow and pointed; but on the abnormal, shortened, fruiting branches one or both of the stipules become broadened and thickened as in the formation of the floral bracts. In Egyptian cotton it is easy to find all these abnormal fruiting branches completing a series of gradations between normal leaves or completely modified floral bracts. That the abnormality of the branches involves in this case the breaking down of the distinctions between the internodes of normal fruiting branches and those of the more specialized floral organs is also shown by the fact that leaf-like bracts are often found as well as bractlike leaves, and that supernumerary petals, divided staminal tubes, and abnormal pistils are of frequent occurrence on plants that show abnormal intermediate forms of branches.

Each of the three bracts that inclose the bud of the cotton plant represents a specialized leaf formed by enlarged stipules united with a greatly reduced blade. In Egyptian cotton it often happens that the leaf subtending a flower bud does not retain its normal size and shape, but becomes more or less intermediate between a leaf and a bract. One or both of the stipules may be enlarged and united with the blade, or the blade may remain separate, with the stalk more or less shortened.

The formation of these abnormal organs shows, as in the case of the branches, a failure to maintain the normal specialization of the parts. The processes of growth that should take place only in the bracts are partly anticipated in the formation of the leaf, the result being an intermediate expression of the leaf and bract characters. Plants that have the bractlike leaves are also likely to have leaflike bracts, more deeply divided at the apex than the normal bracts, and often deeply lobed or cleft nearly to the base.

The liability of the normal specializations to break down may be connected in a general way with the fact of dimorphism of the branches. The fertile branches can be looked upon as inflorescences that have approached the vegetative form and tend to revert to more determinate conditions. The dimorphism of the branches, in such plants as cotton and coffee, means that there are two kinds of vegetative internodes, one forming branches devoted to purely vegetative purposes, the other somewhat intermediate between vegetative and reproductive internodes. Individual internodes which are accessory to the reproductive internodes occur in many plants, just below the flowers. The fruiting forms of specialized branches are made up of such intermediate or slightly specialized internodes.

The practical significance of the abnormalities of the involucre is the same as in the case of the branches. The disturbance of the normal processes of growth are shown to have affected more than the mere external form of the plants. The flower buds that follow the abnormal bractlike leaves are almost invariably aborted, and if the number of such abnormalities is large the plant becomes unproductive or even completely sterile. Such abnormalities have been particularly abundant in the Dale variety of Egyptian cotton, both in 1908 and 1909, but the 1909 planting from seed raised in Arizona in 1908 shows a much larger proportion of normal individuals than among the plants grown from imported seed. Some of the plants of the Dale cotton have the strict upright form of the so-called limbless varieties of Upland cotton, and some produce no flower buds in the normal place on fruiting branches, but only from buds of short axillary branches that appear to represent transformed leaf buds, all other buds being completely aborted. Sometimes all of the buds abort and the whole plant remains completely sterile.

An apparent transformation of the axillary leaf bud into a flower bud is of frequent occurrence in some of the cluster varieties of Upland cotton, but is also common in Egyptian cotton, especially in the Dale variety that has the abnormal branches and bracts.

A transformation of leaf buds into fruiting buds might be expected to increase the fertility of the plants, but this is not the result in the Egyptian cotton for the reason that the most frequent effect of this transformation is to put an end to the growth of a fertile branch. A growing branch must have a leaf bud at the end, and if this terminal bud is transformed into a flower, the branch does not continue. If the transformation is successfully accomplished, we secure one additional boll, but at the expense of a fertile branch which might produce several bolls. The loss is still further increased by the fact that the plants addicted to this habit of transforming leaf buds into flower buds lose a very large proportion of their buds by abortion.

The frequency of abnormalities in the bracts and in the floral organs shows a general disturbance of the normal process of heredity in the newly imported varieties, such as frequently attends hybridization. In the Egyptian cotton varieties it does not appear that these phenomena are directly connected with hybridization, for they occur in large numbers of plants that give no evidence of admixture of Hindi or Upland characteristics. Nevertheless, the whole series of abnormalities may be considered from the standpoint of hybridization, in that they represent intermediate stages between organs of the plants that are normally distinct and different from each other. In each case there is a failure to follow the normal paths of development by which the normal individual advances from the characters of the seedling to those of the adult plant. Although a plant may have all of its characters normally developed in some of its parts, the parts that show the intermediate conditions of the characters may be quite as abnormal as in any hybrid, and resulting sterility is quite the same from the practical standpoint.

The study of the evolution of plant structures has led to the recognition of a phenomenon called translocation of characters, or homœosis, the carrying over into one part of the plant of a character that normally appears in another part, such as the manifestation of the bract characters by the next leaf below the bracts in Dale cotton.[a]

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[a] Leavitt, R. G. A Vegetative Mutant and the Principle of Homœosis in Plants. Botanical Gazette, January, 1909, p. 64.

"In homœosis a character or a system of organization which has been evolved in one part of the body is transferred ready-made to another part. The great mass of instances are of the class called teratological. By this designation we mean substantially that they are suddenly appearing deviations from the customary structures."

In extreme cases a single long-stemmed boll may arise from the axil of a leaf at the base of the fertile branch. This might be taken to indicate a direct transformation of the axillary bud into a fertile branch: but further examination will usually show, even on the same plant, great variation in the pedicels of these axillary bolls, making it evident that they are not simple pedicels, but shortened branches. Small bractlike leaves or stipules are occasionally present, even on straight stems, and sometimes the joint between the branch proper and the true stem or pedicel of the boll remains distinct, even when there are no leaves or stipules. (See Pl. II.)

Where the axillary branches are longer and more definitely jointed it becomes possible to see that the bolls are really borne on a short fertile branch that rises in turn from a short true axillary branch, instead of being inserted directly on the main stem. A shortened axillary branch may represent three normally independent elements, an axillary vegetative branch, a secondary fertile branch borne on the axillary, and the pedicel of the boll, all fused into a simple stem. In some cases it is plain that the true axillary branch has remained entirely undeveloped, for an axillary bud or bud scar can often be found at the base of one of the shortened branches. When no such mark is found it may be supposed that the axillary bud was carried out by the growing branch. It is seldom necessary to suppose that the axillary bud is directly transformed into a flower bud, since the existing conditions can also be reached by fusing the successive joints together, much as they are fused in the formation of a normal involucre.

The idea of translocation may be applied to these abnormalities of the Egyptian cotton, or it may be combined with the idea of hybridization, in view of the many intermediate stages between the parts that are normally quite unlike. The fact that sterility so generally accompanies these intermediate conditions is a further reason for looking upon translocation as a phenomenon akin to hybridization. Changes that might be looked upon as results of partial translocations of characters might also be considered as hybrid metamers or metameric hybrids. They represent abnormal intermediate stages between metamers that are quite unlike when normally developed. They indicate an abnormal intermediate expression of the characters rather than an abnormal transmission of characters to new parts of the plant. All of the hereditary characters are probably transmitted to all parts of the plant, since all of the internodes are able, directly or indirectly, to produce flowers and seeds, but the growth of the normal plant involves the full expression of each character in the appropriate place and its complete suppression in other parts of the plant. Failure of the proper suppression of a character amounts to an abnormality, no less than the failure of a character to come into expression.

These abnormal intermediate forms of branches might also be compared to the hermaphrodite individuals that occur occasionally in plants that normally have the stamens and pistils on separate individuals, such as the fig tree, the date palm, and the hop vine. The diœcious habit is a condition of dimorphism inside the species. The abnormalities of the intermediate individuals support the analogy with hybridization. The behavior of hermaphrodite hop plants has been studied recently by Dr. W. W. Stockberger.[a]

These phenomena are of interest from the standpoint of the study of heredity as well as for agricultural purposes, since they show that characters having little or no direct relation to the external conditions may be seriously affected by changes of environment. New conditions appear to disturb the functions of heredity, not only to bring about substitution of characters and thus cause diversity between the plants, but they also appear to break down specializations inside the plant, to disarrange the patterns, as it were, of the different kinds of internode individuals that form the normal plant.

This conclusion does not refer alone to the fact that these abnormalities are very frequent in the newly imported varieties of cotton, but is also justified by the fact that different parts of the same field may differ distinctly in these respects, as the result of relatively slight differences of external conditions. Even in hybrids that are showing Mendelian segregations of parental characters of branching in the second generation, experiments in different places may give very different results. Hybrids between the Kekchi cotton of Guatemala and the Triumph variety of United States Upland cotton showed, in one place (Del Rio, Tex.), many Triumph-like plants with short basal branches, while at another place (Victoria, Tex.), the same stock of hybrids showed only long branches like the Kekchi parent. Hybrids between Kekchi and McCall, on the other hand, growing beside the Triumph hybrids, showed the short "cluster" branches of the McCall parent very definitely in both localities, and in approximately Mendelian proportions. In the equable tropical climate of Guatemala a planting of the McCall cotton failed to give any indication of the cluster habit that characterizes this variety in the United States.[a]

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[a] Stockberger, W. W. Some Conditions Influencing the Yield of Hops, Circular 56, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910, p. 11.

"In some sections hop vines are occasionally found which bear both staminate and pistillate flowers. Such plants are known locally as 'bastards,' 'mongrels,' or 'bull-hops.' When they occur they represent a total loss, so far as yield is concerned, since the few hops borne by these vines are inferior and never gathered. On the acre under consideration there were only five of these plants, but they have been observed in much greater proportion in other years and in other localities * * *. In 1908 a number of cuttings were taken from one of these 'bastard' plants and removed to a locality about 40 miles distant. The vines from these cuttings came into flower in 1909 and in every case reproduced the malformation of the original plant from which they were taken. In view of this fact care should be taken to prevent the use of cuttings from 'bastard' plants by promptly digging them out and destroying the roots as soon as they are observed. In this way their perpetuation may be prevented and the loss in yield due to their occurrence avoided."

The frequency with which the abnormal intermediate forms of branches occur in all the different stocks of Egyptian cotton that are now being grown in Arizona increases the practical importance of this class of facts. The behavior of other types of cotton during the period of acclimatization has shown that new conditions of growth are able to disturb the processes of heredity and thus lead to many abnormalities of development and often to the complete sterility of the plants, either through failure to form any flower buds or through the abortion of all that are formed.

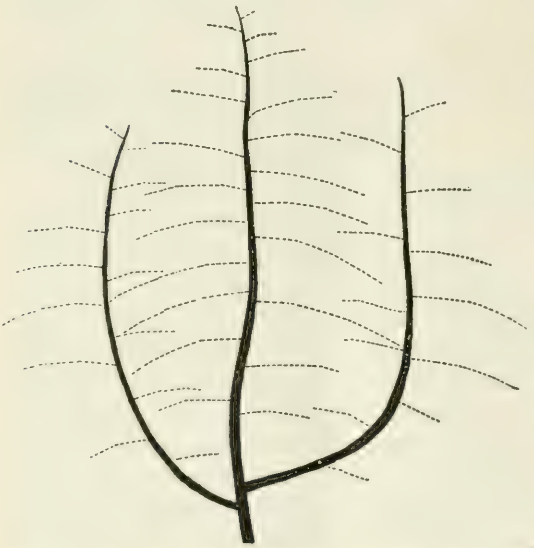

FIG. 1.—Diagram of a cotton plant with two vegetative branches and numerous fruiting branches.

Whether the production of these abnormally shortened branches of the Egyptian cotton is connected with the transfer to new conditions is not so plain as in the case of the abnormal transformations of fruiting branches into vegetative branches, but it is quite possible that the two conditions merely represent the extremes of one long series of variations. In the Dale cotton as grown near Yuma, Ariz., in 1909, the abnormal shortening and abortive tendencies of the branches were much stronger in the plants raised from imported seed than in those produced from seed raised at Yuma in 1908. The larger and more luxuriant plants also showed the greater tendency to abnormal shortening of the fruiting branches, instead of the usual tendency to elongate and change to the vegetative form. The analogy with the cluster habit of Upland varieties is often very strong, and in these also the tendency to abortion of the flower buds is often very great. Under favorable conditions cluster varieties of Upland cotton are sometimes extremely productive, but if unfavorable conditions supervene they are liable to wholesale abortion of the flower buds or the young bolls. The very strong tendency to fruitfulness defeats itself. The plant is under too great a strain of production and suffers the more acutely if conditions become unfavorable.

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[a] Cook, O. F. Suppressed and Intensified Characters in Cotton Hybrids, Bulletin 147, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 23.

RELATION OF DIMORPHIC BRANCHES TO ACCLIMATIZATION.

The recognition of the different behavior of the two forms of branches is an essential step in the scientific study of many of the problems of cotton culture. One of the most striking illustrations of the significance of the dimorphism of the branches has been shown in the study of acclimatization. Central American varieties of cotton that grew under their native conditions as low, short-stalked plants with few limbs and numerous horizontal, fertile branches (fig. 1) showed in Texas a complete change of habits of growth, becoming large, densely leafy bushes, with many strong, sterile limbs, but with very few fruiting branches or none at all. (Compare figs. 1 and 2.)

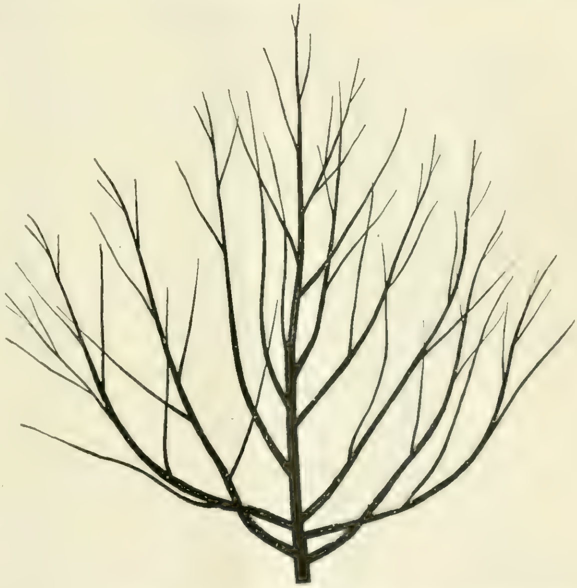

FIG. 2.—Diagram of a cotton plant with numerous vegetative branches and no fruiting branches.

If the change had affected only the size of the plants, it could have been looked upon as a direct result of a rich soil or more favorable conditions of growth, but the complete unlikeness of the Texas plants to their Central American parents showed that other factors were involved. It was possible to raise large-sized plants which still retained the normal form and fertility of the type. The abnormal behavior of the plants was found to arise largely from the fact that sterile limbs were substituted for the normal fruiting branches.

The most extreme result of the transfer to new conditions is shown when the plants fail to form any fruiting branches, all the branches being changed over to the vegetative form (fig. 2). Such plants, of necessity, remain completely sterile, there being no place where fruit can be put on, in spite of the most luxuriant vegetative growth. Where the reaction is less violent the plants are not completely sterile, but produce a late crop, often cut off by frost before any of the seed has ripened (fig. 3). Even when the plants are all able to ripen seed the crop may be cut short and the quality rendered inferior because too many vegetative branches are formed and the bolls develop too late in the season.

A gradual return of the plants to their normal habits of branching has marked the progress of acclimatization. The fertility of the imported stocks has also continued to increase so that many varieties of the Central American cottons are now able to grow in Texas in a completely normal manner, under the same conditions that render plants of the same stocks abnormal and unfruitful if grown from imported seed.

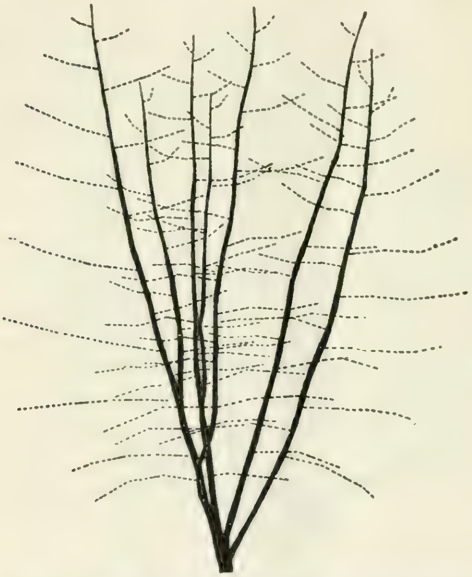
Fig. 3.—Diagram of a cotton plant with six vegetative branches and numerous fruiting branches.

The relation of the factor of branch dimorphism to the problem of acclimatization that first became apparent in dealing with the Kekchi type of Upland cotton from Guatemala has been shown in differing degrees in many other types, including the Egyptian that has been introduced into Arizona and southern California. In all such cases the reduction of the vegetative branches may be looked upon as one of the measures of acclimatization, since it represents a better adjustment to the new conditions. The collection of statistical data on this point in connection with the Egyptian cotton was entrusted to Mr. Argyle McLachlan. A report of his observations on Egyptian cotton growing in the Yuma Valley in the season of 1909 shows very definite contrasts in the production of vegetative branches. Newly imported stocks of Mit Afifi cotton usually produced the first fruiting branches on the fifteenth or sixteenth node of the main stalk, while an acclimatized stock of the same variety began to produce fruiting branches at the tenth node, on the average.

To secure a further reduction of the vegetative branches must be considered as one of the principal problems of adaptation in connection with the establishment of an Egyptian cotton industry in the United States. Experiments have demonstrated that good crops of Egyptian cotton can be grown in Arizona, but the large. branching plants greatly increase the labor of picking and much of the crop is likely to be damaged or lost. The heavily laden branches are very brittle and many of them are broken by the wind or by the pickers. Very large plants are often a total loss, for even the main stalk is likely to break after two or three large branches have split off. Stalks with no vegetative branches very seldom break.

A recent study of cotton culture in Egypt shows that the native method of very close planting is an important factor in restricting the growth of vegetative branches, but the scarcity of hand labor would forbid a direct imitation of the Egyptian system in the United States. Experiments are now to be made with modified systems of close planting adapted to machine culture. It may prove desirable to leave three or more plants in a hill, instead of one, if the vegetative branches can be suppressed in this way. Attention is also being given to the selection of early, productive plants with few vegetative branches or none. Varieties of Upland and Sea Island cotton have been developed which seldom produce any vegetative branches.

RELATION OF BRANCH DIMORPHISM TO WEEVIL RESISTANCE.

Cotton varieties that develop the extra-axillary vegetative branches instead of the axillary limbs are very poorly qualified for early fruiting and determinate habits of growth, which have been considered as means of avoiding the injuries of the boll weevil. One of the difficulties of combating the weevil by cultural methods lies in the fact that our Upland cottons continue to produce a succession of superfluous buds, in which weevils are bred throughout the growing season. If the weevils did not have a succession of buds to feed upon, breeding would diminish in the latter part of the season, and the number that could survive the winter would be greatly reduced. The pollen diet seems to be absolutely necessary to enable the weevils to complete their life history. Until they have fed upon pollen the adults very seldom copulate and never lay eggs.

Of all the types thus far known, the Kekchi cotton of Guatemala comes the nearest to the ideal of a determinate habit of growth, for it is able by means of its ready development of axillary limbs to secure abundant foliage without being compelled to continue the formation of flowering buds. Varieties which have no vegetative limbs have no leaves except those of the main stem and the fruiting branches. Fruiting branches produce only as many leaves as flower buds, a bud at the base of each leaf. Varieties that do not produce vegetative branches must put on more flower buds in order to produce additional leaves.

Even when the weevils are not present a large proportion of the buds and young bolls of our Upland cottons are generally thrown off as superfluous, the vegetative energy of the plant not being adequate to bring them to maturity. Selection has probably tended toward the elimination of sterile branches in our Upland types of cotton. As long as the weevils did not enter into the problem, the superfluous buds, though no doubt causing a large waste of the productive energy of the plant, had a compensating value as a kind of insurance of the crop, for if in an unfavorable season the early buds were lost their places were filled by numerous successors as soon as the weather improved.

With the advent of the weevil it becomes a matter of importance to do away, if possible, with this persistent prodigality of bud formation. At the same time it is essential that the growth of the plant continue, at least to the extent of producing leaves enough to serve adequately the purposes of assimilating food for the growth of the bolls. The Kekchi cotton, by making use of primary branches, suggests a factor that has a relation to the problem, by showing how more foliage can be produced without the need of making the extra number of floral buds which are likely to serve only as breeding places for the weevils.

Many other kinds of plants, the great majority, indeed, have the determinate habits which would be so great an advantage in cotton in dealing with the weevil, for they produce buds and blossoms for only a short interval. Some plants can be made to continue in blossom by having their flowers picked so that seed can not set. To have educated the cotton plant to such determinate habits by selection might have proved a difficult and time-consuming labor. But with the realization of the fact that the cotton plant has two distinct kinds of branches, one of which does not produce flower buds, the task of finding or securing by selection a regularly determinate variety of cotton appears more definite and practicable. The possibilities of utilizing at the same time others of the numerous weevil-resisting adaptations possessed by the Kekchi cotton and other Central American varieties have received detailed consideration in a previous report.[a]

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[a] Cook, O. F. Weevil-Resisting Adaptations of the Cotton Plant, Bulletin 88, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1906.

The application of branch dimorphism to the problems of weevil resistance is not necessarily limited to early fruiting and determinate habits of growth. While early fruiting is undoubtedly an advantage under the ordinary conditions of cotton-growing communities, it does not necessarily follow that late-fruiting types of cotton will be permanently excluded from cultivation in all weevil-infested regions. Late-fruiting varieties must always suffer worse, of course, when grown with early varieties, but if the late-fruiting varieties were grown exclusively by whole communities the disadvantage would be less and might be avoided entirely if varieties were secured which were able to set a crop of bolls within a short time after the production of flower buds began. As long as the weevils were left without pollen to feed upon, and were thus unable to breed, the danger from weevils would not be increased. A quick-fruiting late variety, grown by itself, would have the same advantages of weevil resistance as an early variety grown under ordinary conditions, and with the prospect of being able to set a larger crop of bolls than the small plants of an extra-early variety.

DIMORPHIC BRANCHES OF THE CENTRAL AMERICAN RUBBER TREE.

The differences between the two kinds of branches in the Central American rubber tree (Castilla) correspond in some respects to those of the cotton plant. All the flowers and fruits are borne by one kind of branches, while the other kind has vegetative functions only, like the main trunk of the tree. But with regard to the origins of the two kinds of branches, the rubber tree is directly contrasted with the cotton plant. The fertile branches of Castilla always come from axillary buds, while the vegetative branches are always extra-axillary.

The diversity of function is carried a step farther than in the cotton plant, for the fertile branches do not become a permanent part of the tree. After they have borne two or three crops of fruit they separate neatly from the trunk and drop out of their sockets, which soon heal over. The dimorphic nature of the branches of the genus Castilla and the self-pruning habit of the fruiting branches have been described and illustrated in a former publication.[a]

Except in very rare instances, the fruit-bearing branches of Castilla remain quite simple and produce only leaves, followed in the next year by a cluster of flowers above each of the leaf axils. Growth takes place only at the end of the branch, leaving a longer and longer naked section at the base after the successive crops of leaves and fruits have fallen. Finally the weight of the branch becomes too great for the support, the soft basal joint gives way, and the branch drops to the ground. The base of the branch is conical or rounded, and fits into a socket in the wood of the trunk. Both the base and the socket are marked with very fine radiating ridges and grooves, showing that the self-pruning habit of the tree is the result of a definite specialization of tissues and not a mere breaking or rotting away. In fact, the branch is usually still alive when it falls, and milk flows out of the tree into the exposed socket to cover the wound. The bark also soon grows over it and heals completely, leaving only a faint, rounded scar.

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[a] Cook, O. F. The Culture of the Central American Rubber Tree, Bulletin 49, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1903, p. 20, pl. 10.

The upright or permanent branches of Castilla are comparatively few in number. They arise, one in a place, at the right or the left of the base of a temporary branch, with the same regularity as in a stalk of cotton. They take a much more oblique or upright direction than the temporary or fruiting branches, which are usually nearly horizontal or somewhat drooping. The trees often grow to a height of 15 or 20 feet before any of the permanent branches develop, and then they often appear singly or a few at a time. (See fig. 4.)

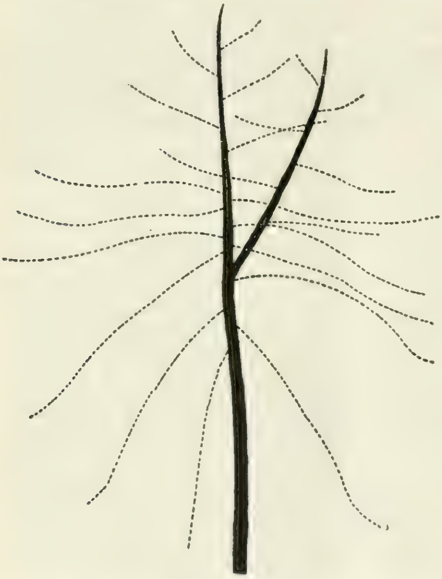

FIG. 4.—Diagram of a rubber tree with one permanent vegetative branch and numerous temporary fruiting branches.

The idea that extra-axillary buds are abnormal or exceptional appears to be quite as unwarranted in Castilla as in cotton. It would be possible for a Castilla tree to grow to seed-bearing maturity without producing any extra-axillary branches, but there would be formed in this way only a simple upright stalk or trunk. All of the branches that form the true permanent framework of the tree arise from extra-axillary buds that might be considered adventitious. Whether such buds are added after the formation of the internodes that bear them or are formed with the internodes and remain dormant at first is not certain. A permanent branch is often put forth at the base of a temporary branch that is still very young, in trees of sufficient age. That permanent branches of Castilla can arise as truly adventitious buds is indicated by the fact that they often appear in considerable numbers along the edges of wounds, as when the bark is healing over gashes made in extracting rubber.

RELATION OF DIMORPHIC BRANCHES TO METHODS OF PROPAGATION.

There is no reason to suppose that the fruit-bearing branches of Castilla would take root, or that they could develop into normal trees. Sections of the trunk or of the permanent branches, on the other hand, take root readily, often when merely driven into the ground as fence stakes. In the Soconusco district of southern Mexico many instances were observed in which rubber trees were growing with apparent health and vigor from plantings as fence stakes. One of the largest rubber trees in the vicinity of Tapachula is said to have grown from a fence stake.[a]

The fact that the Central American rubber tree is capable of being propagated from cuttings is of practical interest in connection with the great differences in yields of rubber from individual trees. Though external conditions are undoubtedly responsible for some of the differences, there is every reason to believe that the characteristics of the individual trees will prove as important as among other cultivated plants. A system of vegetative propagation would enable such differences to be utilized directly, whereas an attempt to develop improved strains that would come true to seed might require many years of breeding. The utilization of the increased vigor and fertility of hybrids might also be made possible by a system of vegetative propagation.

The use of large cuttings in setting out new plantations would have cultural advantages in more quickly reestablishing the forest conditions that are now considered desirable in rubber plantations. Two of the systems of managing plantations that were quite popular at first have been found to have serious disadvantages. The leaving of the old forest to keep down the undergrowth by shade interfered also with the growth of the young rubber trees. Clean culture allows the trees to grow very rapidly at first, but their later development may be checked if the fertile surface soil is washed away and harmful grasses become established. The cleaning of the grassy plantations becomes more and more expensive, and also more and more harmful. The expected rate of growth of the trees is not maintained, and the period of profitable production of rubber recedes into an indefinite future.

Other difficulties in rubber culture come from the refusal of the latex to flow from the trees. Even when an encouraging yield is obtained from first tappings, later attempts to secure latex from the vicinity of an old cut may be very disappointing. In the Para rubber tree (Hevea) there is a so-called "wound response" that results in continued and increased yields of latex from the paring back of the edges of the wounds, but in the Central American rubber (Castilla) the tapping of the bark in the vicinity of old cuts may bring out very little latex. The bark pressure that forces the latex out of new cuts is not restored around the old cuts. Only a small proportion of the latex is extracted by the present methods of tapping; the rest remains and dries up in the bark. If bark could be produced more rapidly by vegetative propagation, it might become practicable to harvest the bark as well as the latex and extract the rubber by mechanical means. Branches from the more productive trees would be available for extending the plantation.

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[a] Cook, O. F. The Culture of the Central American Rubber Tree, Bulletin 49, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1903, pl. 9.

THE PRUNING OF RUBBER TREES.

The fact that the rubber tree prunes itself so extensively leaves little work of this kind for the planter to do, but two precautions are not unworthy of consideration. The self-pruning mechanism does not always work successfully. If growth is very rapid the trunk may enlarge around the bases of the temporary branches and hold them in place, even after they are dead. This is also likely to happen when a branch has been injured or dwarfed, and thus lacks the weight necessary to break it away from its socket. Such decaying branches may give fungi or insects an entrance to the wood of the tree and thus induce decay. It would require very little additional labor to keep the plantation entirely clear of them. In most cases a pole with a simple hook or elbow at the end would enable them to be pulled out of their sockets, which would be better than cutting them off. The pruning away of some of the permanent branches may be desirable in the occasional instances where these come out too low down. The earlier these are removed the better, to keep the trunk of the tree smooth and erect for purposes of tapping.

DIMORPHIC BRANCHES OF COFFEE.

The upright branches or limbs of the coffee shrub are the equivalents of the original main stem; they bear no fruit, but can give rise to other uprights and to lateral branches. (See Pl. III.) The laterals bear flowers and fruit, and can also give rise to other branches of the same form and function, called secondary laterals, or simply secondaries, but no lateral branch ever produces a true upright branch. Unlike the cotton plant and the rubber tree, each internode of coffee bears two opposite leaves and is capable of producing two sets of branches, two axillary and two extra-axillary. In rare cases an internode may bear three leaves and the branches may stand in whorls of three.

The buds that give rise to the upright limbs make their appearance in the normal position, in the axils of leaves, but the lateral branches develop in advance of the leaves of the joint to which they are attached, and appear to arise from near the bases of the joints or internodes of the uprights, instead of from the ends of the joints. (See Pl. IV.) They do not appear to have any connection with the leaf which is nearest them below. There is no difference of texture or line of separation between the upright and the young lateral branch. Both are covered from the first with the same continuous skin or epidermis, without groove or wrinkle. The lateral branches do not fall off or separate from the upright except by decay.

The lateral branches are always formed while the joint is young and growing, instead of pushing out afterwards, as do the adventitious or dormant buds. In this respect there is an abrupt difference between the primaries or first generation of laterals and the second generation or secondary laterals. These arise from the primary laterals at the axils of the leaves. Secondary laterals are seldom produced when the uprights are allowed to grow normally, but the growth of secondary laterals can be forced by severely pruning the uprights. Under unfavorable conditions, where the growth of the plants is alternately checked and forced, the formation of supernumerary secondary laterals represents a diseased condition, somewhat resembling the “witches’-brooms” of some of our northern trees. (See Pl. V.)

The axils of the lateral branches usually produce only flowers and fruits. The floral buds appear in large numbers clustered on several very short axillary branches. The secondary laterals can thus be understood as representing sterilized floral branches. Flowers are not normally formed on uprights. In the Bourbon coffee, which is abnormally prolific in flowers, the uprights are occasionally fertile to a slight extent.

PROPAGATION OF COFFEE FROM OLD WOOD OF UPRIGHT BRANCHES.

The prevalent idea that coffee can not be grown from cuttings has arisen, presumably, from attempts made with lateral or secondary branches (fig. 5). Pieces of the main stem or of upright branches take root readily and produce entirely normal trees. Several very successful examples of vegetative propagation of coffee from upright branches have been seen in Central America, though all were results of accidents, not of any definite intention to apply a new method. In such towns as Coban and Purula, in the coffee-growing districts of the mountains of eastern Guatemala, one often finds fence stakes of old coffee wood putting out new shoots and forming new tops like vigorous young trees in a plantation.

Other cases were found in Costa Rica on the large coffee estate of Señor Don Federico Tinoco at Juan Viñas. Straight stakes cut from old coffee trees had been used to support the bushes in the rose garden of Señora Tinoco, and had promptly taken root. They had been allowed to grow, and had all developed into large, well-formed, productive coffee trees. Such instances certainly demonstrate the possibility of producing normal coffee trees by vegetative propagation. As there are considerable differences of soil and climate between Costa Rica and eastern Guatemala, it appears that such propagation is not narrowly limited to one set of conditions.

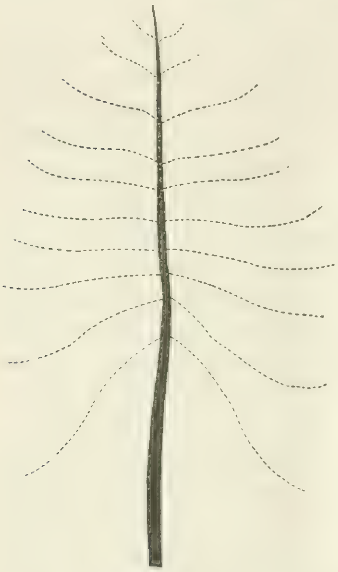

Fig. 5.—Diagram of a coffee tree with a simple trunk and numerous lateral fruiting branches.

If a system of vegetative propagation could be applied to coffee by the use of cuttings of the upright branches (fig. 6), several important cultural advantages might result. Much of the labor and expense now required for seed beds, nurseries, and transplanting would be saved, and plantations might be brought more rapidly to the size when good crops are produced and the ground is well shaded by the trees. The latter condition not only reduces the cost of cleaning the land of weeds, but protects it from injurious exposure and erosion.

The possibility of improving the coffee crop by the development of superior hybrid varieties also depends upon the use of some system of vegetative propagation, or upon the grafting of the young seedlings, as has been proposed in Java and other tropical countries. At present we have only the so-called Arabian type of coffee and the several mutative varieties which have been selected from it. Most of these, if not all, are inferior to the parent stock in fertility. Although very satisfactory in the matter of coming true to seed, they all seem to lack the first essential of an improved type, for they are generally less fertile than the parent stock.

In addition to the precaution of using the upright branches, other methods of treating the propagating stock will need, of course, to be worked out. It is quite possible that the cuttings can not be used in a fresh condition, but may need some process of curing after they are cut, such as would allow new tissues to form on the cut surfaces before they are placed in the ground. In the successful cases of propagation from cuttings mentioned above, the wood had come from old trees that had been taken out of the plantations. Time may also have elapsed between the cutting of the stakes and the setting of them in the ground.

RELATION OF BRANCH DIMORPHISM TO THE PRUNING OF COFFEE.

The habits of growth and cultural requirements of coffee, and especially the principles of the art of pruning, can not be clearly understood without the recognition of the two kinds of branches. Planters who reason in a general way, without taking into account the dimorphism of the branches, often suppose that the pruning back of the uprights at the growing ends will cause them to send out new lateral fruiting branches lower down. This is a mistake, for new lateral branches are formed only on young, growing uprights, and then only two of the laterals from each joint of the upright.

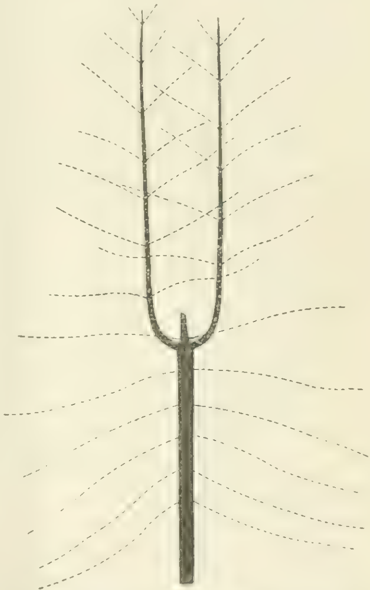

Fig. 6.—Diagram of a coffee tree with two upright branches and numerous lateral branches.

Additional development of lateral branches is to be obtained from mature uprights only by forcing the primary laterals to send out secondary laterals. If the primary laterals have been cut off no secondary laterals can be formed. Severe cutting back of the main trunks or upright branches is usual as a means of forcing more vegetative growth in the lateral branches. If the pruning is too slight it may have the effect of merely causing the primary laterals to elongate without forcing them to send out secondary lateral branches, for it is not a normal habit of the coffee tree to produce branches from the laterals. Left to itself without pruning, coffee usually produces only simple laterals and forms new lateral growth only through the medium of new uprights.

When all the axillary buds of the main stem have been eradicated no new uprights can be formed. If the tree continues to thrive, it spreads out on the ground as a tangled mass of slender decumbent lateral branches. It is the custom of planters in Jamaica, according to Mr. G. N. Collins, of the Bureau of Plant Industry, to pull off the uprights instead of cutting them, on the ground that this prevents the growth of any more uprights. It is easy to understand that additional uprights may develop from buds of short basal joints of uprights that have been cut off, but this would not be the case with uprights that are pulled out. An additional bud can be seen on Plate IV, underneath the base of one of the new uprights that have been forced by pruning.

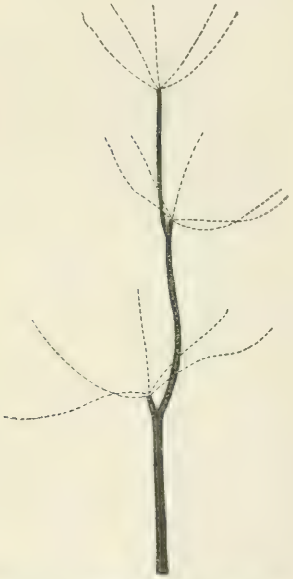
FIG 7.—Diagram of a cacao tree with three upright shoots and three groups of whorl branches.

If the fertility of a plantation is to be maintained, resort must be had to some form of pruning, in order to continue the formation of healthy new wood on which good fruit can be borne. Old trees that are not pruned tend to produce slender branches, narrow leaves, and very small fruit. New wood can be obtained by allowing new uprights to develop or by preventing the growth of the uprights and forcing the laterals to branch. The use or the rejection of the uprights affords a fundamental distinction between the several different systems of pruning coffee.

The subject is one of too great extent and complexity to be discussed in detail here. Methods that may be thoroughly justifiable and advantageous under the conditions of one coffee-growing district may be objectionable in another, or even destructive, so greatly do the habits of the plants differ under different conditions of climate and soil. The practicability of the different systems of pruning depends also very largely upon the character and cost of labor. In some countries the natives show much aptitude for such work, but in others only the simplest systems can be applied; the cost of skilled assistance would be prohibitive.

DIMORPHIC BRANCHES OF CACAO.

The cacao tree bears two distinct kinds of branches, but these do not correspond directly to those of the rubber tree, the coffee, or the cotton. The fruit-bearing function is not confined to either type of branches. Both have vegetative functions, and both produce the small leafless twigs that bear the flowers and fruits. Even the main trunk of the cacao tree produces flowers and fruit in the same way as the branches. In other words, cacao is cauliflorous.

The two kinds of vegetative branches can be distinguished readily by their position and also by the fact that they bear different kinds of leaves. The trunk elongates by a succession of upright shoots, each of which is terminated by a cluster or whorl of branches (fig. 7). (See Pl. VI.) The main stem and the upright branches have leaves with distinctly longer petioles than those of the lateral branches. The petioles of the leaves of the uprights are often 3 inches long, while those of the whorl leaves are less than an inch. (See Pl. VII, fig. 1.)

In the patashte tree (*Theobroma bicolor*), a relative of the cacao that is being introduced into cultivation in Guatemala, the specialization of the leaves of the two types of branches is carried still farther. The leaves of the main trunk and the upright limbs have petioles 8 or 10 inches in length, while the leaves of the secondary or lateral branches have petioles only about 1 inch long, as in the cacao. The blades of the two kinds of leaves of the patashte are also very different in size, shape, and texture, instead of being nearly alike as in the cacao.[a]

When a cacao seedling has grown a simple straight stem to a height of 2 to 4 feet, the single terminal bud gives place to a cluster or circle of three to six small buds, from which arises a whorl of as many branches. (See Pl. VI.) These branches soon diverge in a horizontal or oblique direction, but curve upward toward the end. In the petashte tree the number of branches in each whorl is always three, but in the cacao there are usually four, often five, and occasionally six. The whorled branches do not continue the upward growth of the main stem or trunk of the tree, but a new shoot for this purpose appears, in due time, on the side of the trunk, often an inch or more below the terminal whorl of branches. This lateral shoot curves upward and passes between two of the whorled branches into a vertical position, grows a few feet upward, and divides into another whorl of branches. Later on these upright sections seem to straighten more and more until the clusters of branches, which had previously terminated the trunk at its different stages of growth, are pushed over to the side, as though they were lateral clusters.

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[a] The patashte tree also differs from the cacao in not being cauliflorous. The short inflorescence branches do not rise from the old wood of the main trunk and larger basal branches, but are confined to the axils of new leaves near the slender growing ends of the branches. The patashte is a much taller tree and grows much more rapidly than the cacao. It is usually from 12 to 20 feet high before it begins to branch, instead of branching within 3 or 4 feet of the ground, as the cacao usually does.

RELATION OF DIMORPHIC BRANCHES TO HABITS OF GROWTH.

Other cacao trees, both wild and cultivated, fail to show these habits of growth. Instead of the erect main stem, with branches in rosette-like clusters, the trunk divides near the ground into many oblique arms that form a broad spreading top of dense foliage, entirely unlike the open, irregularly distributed foliage of the trees with tall upright trunks. Planters of cacao have recognized cultural differences between the two forms of trees, the low, spreading type being preferable for plantation purposes to the tall type with the whorled branches.

It has been supposed that the different habits of growth betoken two different varieties of cacao, but seedlings from the spreading trees have not been found to show any tendency to reproduce the spreading habit of growth. If the spreading trees had any other character in common, the idea of a varietal difference might still appear to have some justification, but the fact is that both kinds of trees show the same general range of individual differences in the characters of the fruits, which are the only parts of the plant that lend themselves to careful comparison. The serious difference lies in the fertility, for the low, compact trees that shade their own short trunks and the ground underneath them appear to thrive much better in plantations than trees of the other type, and bear larger crops. In eastern Guatemala, where this matter was studied in some detail, it was the opinion of a very intelligent cacao planter, Don Ricardo Fickert-Forst, owner of the Trece Aguas estate, that the low, spreading trees would bear, on the average, at least twice as much cacao as the others, and that they would continue to be fruitful for a longer period of years. Efforts had been made to obtain more of the spreading trees by planting seeds from trees of this form.

The failure of such attempts can be explained after the serious differences between the two kinds of branches are recognized. The low, spreading trees have this desirable form because they do not produce any of the upright shoots and whorls of branches. Their method of branching is the same as that shown on whorl branches, that are incapable of forming uprights, as already explained. Although there is no indication of a whorled arrangement of the main branches of the spreading trees, it may nevertheless be considered that the tops of these trees represent the development of only one or two of the branches of an original whorl, and this would afford an adequate explanation of the formation of a different type of tree.

The inability of the whorled branches to produce any upright shoots would explain why a tree top formed from such a branch would not have any of the strong upright shoots, but would produce only the relatively slender oblique or lateral shoots proper to the branches that are formed as members of a whorl. If only one or two of the branches of the first whorl were to survive and to begin branching near the base, the further growth of the tree might come from the development of these whorled branches, the upright type of the branches falling into complete abeyance. The question of being able to produce at will the desired type of tree appears to turn on the treatment of the young tree at the time it puts out the first or second whorl of branches.

RELATION OF DIMORPHIC BRANCHES TO THE PRUNING OF CACAO.

Recognition of the dimorphism of the branches of the tree is a matter of even more fundamental cultural importance with cacao than with coffee, since it enables us to understand differences in habits of growth that determine the productiveness and even the life of the trees. Much of the advice regarding the pruning of cacao has been given without regard to the dimorphism of the branches, and is misleading, if not actually dangerous. Some writers have recommended the removal of some of the branches of the lowest whorl if the tree begins to branch too low down, and others have held that only three or four of the whorl branches should be allowed to develop when five or six are produced. In neither case has it been considered that the preliminary treatment might have the effect of a complete alteration of the habits of growth of the tree.

If the production of whorled branches is to be allowed to continue so as to produce trees of the upright, open form, it is very doubtful whether any advantage can be gained by removing a few of the branches of a whorl. The effect is to weaken the basal ring of wood that supports the whorl in its rather precarious position at the end of the long, upright shoot. When the strength of this ring is diminished the weight of the branches is likely to split them apart. Moreover, the wood of the cacao tree is so soft that decay is very likely to follow any injury—another reason why any attempts at pruning should be confined to the very youngest stages of the growth of the branches.

If an attempt is to be made to compel the young tree to form its crown from one or two of the whorl branches, it is also very important that these keep the more nearly upright position that they have in their early stages. If pruning be delayed until the whorl has opened out and the branches have become nearly horizontal, the chances of having a well-shaped crown are very small. It may also be desirable not to let the branches that are left grow too long. Pinching off the end when they are about a foot long would force them to send out secondary or lateral branches near the base and thus assist in forming a compact, well-shaped crown. With two or more strong branches from near the base of a single whorl branch a condition somewhat similar to the original whorl may develop, but essentially different in the subsequent habits of growth, since these branches do not tend to spread apart like true whorl branches, and are able to continue the upward growth of the tree without the formation of any more upright shoots from the main trunk.

A further indication that the habit of forming the whorled branches represents a definite specialization may be found in the fact that the upper leaves of an upright are often aborted. The stipules are of the normal size, but the petioles and blades do not develop. The stipules soon drop off, leaving small scars on the surface of the bark as the only indication of the joints.

It is not clear whether this habit of forming abortive leaves is to be viewed as an adaptation to avoid the clustering of too many leaves at the top of an upright shoot, or is connected with the shortening of the internodes to form the whorl of branches. When the leaves are aborted many short internodes are likely to be formed below the whorl. In other cases there are no abortive leaves. Even the whorled branches may arise from axils of normal, full-sized leaves, but in such cases the whorl is likely to be somewhat irregular, as though the internodes had not been sufficiently shortened.

If these reduced leaves are taken into account, the cacao tree may be said to have three kinds of leaves, the leaves with the long petioles on the lower parts of the uprights, aborted leaves at the ends of the uprights, and short-petioled leaves on the whorled branches. The specialization of the leaves of the cacao is somewhat similar to that of the pine tree. Young seedlings and new shoots of pines that have been cut down or severely pruned have functional green leaves all along the shoot. Ordinary shoots and branches of pine trees have no functional green leaves, but only scalelike membranous sheathing leaf bases. The functional leaves of adult pine trees represent the terminal clusters of a few leaves at the ends of very short specialized branches that appear to be incapable of further growth. New branches have to be developed from special zones where the axillary buds of the leaves of the uprights remain dormant instead of producing the short leaf-bearing branches.

The habit of the cacao tree to produce the long uprights with a whorl of branches at the end appears thoroughly undesirable from the cultural standpoint, but if we consider the habit of the wild cacao to grow in dense thickets with many other kinds of woody vegetation its peculiar habit of growth may be seen to have some advantages. The rapid growth of the upright shoots enables a cacao tree to raise a terminal whorl of branches above the surrounding vegetation, and thus secure an amount of exposure to sunlight that might not be obtainable otherwise. Though the cacao must be reckoned as one of the shade types of vegetation it does require light. The most vigorous and productive cacao trees are those that stand out in full exposure to the light, but the soil conditions must be very favorable to enable the trees to thrive with full exposure.

DIMORPHIC BRANCHES OF THE BANANA PLANT.

Although the habits of growth of the banana plant are altogether different from those of the shrubby and woody species previously described, there is a definite dimorphism of branches that has to be taken into account in studying the habits of growth and the problems of cultivation. Banana planters regularly distinguish between "sword suckers" and "broad-leaved suckers," but the nature and the extent of the differences between the two kinds of offshoots have not been adequately appreciated. The effects of external conditions have been supposed to explain the differences, although both kinds of branches are almost always to be found on any well-developed plant.

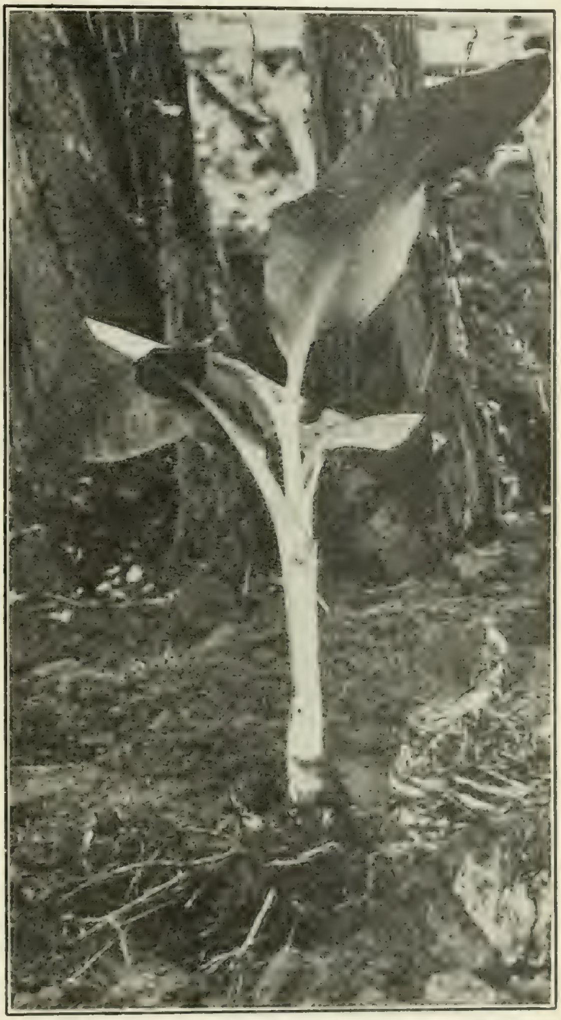
FIG. 8.—A broad-leaved sucker of a banana plant from Costa Rica. (Greatly reduced.)

The names of the two kinds of offshoots allude to differences in the size and shape of the leaves. The broad-leaved suckers begin near the ground to produce leaf blades of the same general form as those of the adult plant (fig. 8). The sword suckers produce at first only small narrow blades that by their shape suggest the name (fig. 9). The basal, sheathing parts of the leaves that form the so-called "trunk" of the banana plant are much larger in the sword suckers, and this renders the reduction of the blade of the leaf a more evident specialization.

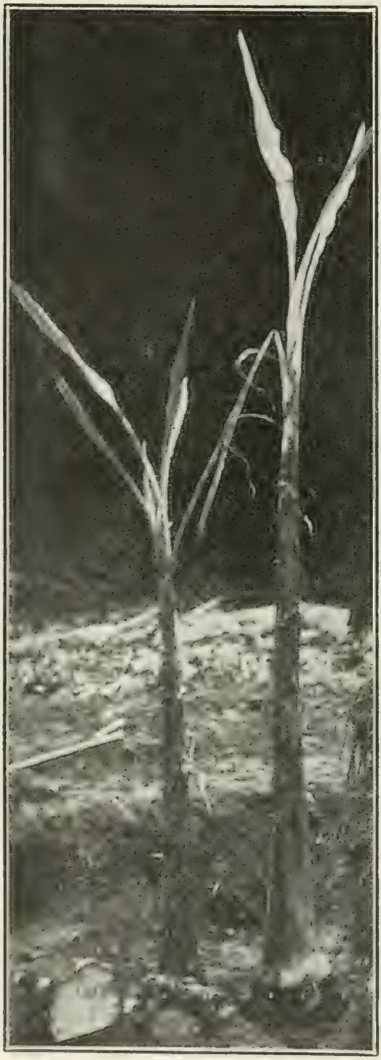

FIG. 9.—Sword suckers of the commercial banana, used in setting out plantations in Costa Rica. (Greatly reduced.)

Possibly the dimorphism of the branches is not as definite in the banana as in the woody plants previously considered. Though no connecting stages between the two kinds of branches were noticed in the rootstocks that were dug out and examined, it may be that intermediate conditions will be found occasionally, as in Indian corn. The intermediate joints of corn plants, between the ears and the suckers, seldom develop branches, but when such branches are developed they are intermediate in form, as well as in position.

The differences in the development of the leaves call attention at once to the fact that the two kinds of banana suckers stand in different relations to the parent plant. The broad-leaved suckers, with their relatively large, expanded leaves, are able from the first to elaborate a larger part of the nourishment they require than are the sword suckers, yet in spite of this apparent advantage the broad-leaved suckers are of much slower growth. It is evident from this fact that the sword suckers stand in a different relation to the parent plant and draw a much larger proportion of nourishment from it.

These differences of relation are made still more obvious when it is learned how the two kinds of branches originate. The broad-leaved suckers come from buds around the sides of the rootstocks, near the surface of the ground. The sword suckers begin their development deep in the ground, underneath the parent rootstock. They have at first the form of slender, subterranean shoots, that grow first in a horizontal direction or even obliquely downward. They thicken into a large fleshy bulb before beginning to grow much above ground. (See Pl. VII, fig. 2.)

The sword suckers may be looked upon as true permanent branches of the parent rootstock, while the broad-leaved suckers are better adapted for separate propagation under natural conditions. Many of the latter are put out above the surface of the ground. Some of them have at first the form of small, rounded tubers, the buds remaining entirely dormant. A banana plant that has been uprooted by the wind does not die at once, but puts out from about its base a large number of these potato-like tubers, which finally fall off and are readily scattered, or roll down hill. The wild relatives of the banana plant are natives of steep, rocky hillsides, where such a method of vegetative propagation would be distinctly advantageous.

CULTURAL VALUE OF TWO TYPES OF OFFSHOOTS.

Banana planters generally follow the rule of using the sword suckers in setting out plantations, on the ground that they produce fruiting plants quicker than the broad-leaved suckers. This is easy to believe, in view of the larger amount of stored nourishment that is carried over to the new plants by using the much thicker bulb of the sword suckers instead of the relatively small rootstocks of the broad-leaved suckers. Some planters in Costa Rica doubt whether the broad-leaved suckers ever produce fruit of their own, and are inclined to believe that fruiting does not begin until the necessary sword suckers have had time to grow. In Jamaica, on the other hand, the sword suckers are cut back nearly to the ground before planting and the first crop comes from the growth of new suckers.[a]

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[a] See Stockdale, F. A., "The Question of a Banana Industry," Journal of the Board of Agriculture of British Guiana, vol. 3, no. 2, 1909, p. 79.

"The suckers which would be selected for planting [in Jamaica] are not the same as those that would be chosen in this colony [British Guiana], and the method of treatment is totally different. Suckers for planting purposes are suckers that have not been cut back, or in other words, 'sword suckers'—as indicated by their first leaves being very narrow—which have been allowed

The use of the most vigorous suckers appears especially important, not only to obtain the earliest possible crop from a new plantation, but because it is also highly desirable for a new plantation to grow up rapidly and shade the ground as soon as possible, thus protecting itself from harmful weeds and lessening the cost of cultivation. The later welfare of the plantation may also be affected by its early prosperity. The shading of the ground not only helps to maintain favorable soil conditions and thus conduces to larger crops, but larger numbers of the quick-growing sword suckers are produced in prosperous, shady plantations. The exposure of the base of a banana plant to much light appears to stimulate the formation of broad-leaved suckers, as though the plants had the intention to occupy the surrounding land before turning their attention to the production of fruit.

THE PLANTING OF RESTING TUBERS.

Although the production of many broad-leaved suckers may be considered to represent an unfavorable condition in a plantation, they are not without interest and utility from other points of view. The much greater abundance in which the broad-leaved suckers are produced would render them of very distinct importance in any attempt to propagate a new variety or special strain derived from a single superior plant. A rootstock can not be expected to produce more than three or four sword suckers at one time, while a score, or perhaps several scores, of broad-leaved shoots might be obtained if a plant were treated with this end in view. Study might well be given to the finding of differences in habits of branching. A strain that would produce only a few suckers would be more valuable in the plantation, for the pruning away of superfluous suckers is one of the chief items of expense in many banana plantations. Such a strain might be at a disadvantage, however, in furnishing stocks for new

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to grow to about 8 or 10 feet in height and which have large bulbs at their base. No small suckers, such as we choose in this colony, are taken. In preparing their suckers for planting the Jamaicans cut down those selected to within about 6 inches of the ground and then dig out the bulbs. All the old roots are then trimmed off, and the bulb is planted so that the eyes are at least 3 or 4 inches below the level of the ground. From this bulb three or four suckers will spring up. The strongest one is selected, and all the others are pruned off until June, when one or two suckers are left, and then, again, all others are pruned off until October, when there is again left either one or two, and finally another is left the following February. It is calculated that the first suckers should fruit in the following March, the June suckers in May, the October ones in February or March, twelve months, and the February one in May or June, twelve months. This system for timing is the outcome of long experience and could not be adopted in this colony without modification on account of differences in climatic and rainfall conditions."

plantations, unless it could be made to yield more numerous offshoots when these were required.

The use of the hardened resting tubers may be considered as the ideal condition for shipping propagating stock of the banana from one country to another. The question of diversifying the American banana industry by the importation of some of the superior types of banana of the Old World has often been raised. One of the difficulties has been to obtain new stocks in sufficient quantity, even for adequate experiments to be made. This has appeared to stand in the way of any immediate practical results being obtained, and has undoubtedly tended to discourage attempts to obtain superior varieties.

It is also possible that the broad-leaved suckers may be found useful in dealing with some of the banana diseases that appear to indicate a weakening of the vitality of some of the best strains of the commercial banana, as in the case of some of the superior varieties of sugar cane. The sugar planters of Java bring down new stock from the mountains, because the mountain-grown canes have been found more resistant to disease than the same variety grown continuously in the lowland plantations.

The tuber-like, broad-leaved suckers that are formed on uprooted banana plants may be looked upon as a resting state, and may be expected to have a relation to subsequent vigor of growth. An interruption of growth might be directly beneficial, or if different conditions prove to be necessary, as in the case of the sugar cane, the tubers would greatly facilitate the exchange of propagating material. They could be collected and transported from one district to another much more readily and cheaply than the large, heavy sword suckers.

As a means of testing the possible effect of the resting stage upon the subsequent behavior of the plants, a suggestion was made in 1903 to Prof. H. Pittier, who soon after took charge of the experimental plantations of the United Fruit Company in Costa Rica, that plantings be made of these potato-like tubers to see whether any differences of behavior would be shown. In 1904 a hectare (about 2½ acres) of land was planted with these small resting tubers, instead of the usual sword suckers. The growth of the plants was unexpectedly rapid and did not fall behind that of the neighboring fields that were planted with large sword suckers. The first crop was matured in about nine months, the usual time under the Costa Rican conditions, and with more than usual uniformity, each plant producing a large, well-formed cluster of fruit. It was also noticed that the plants of this field produced very few suckers around the base until after fruiting, in very distinct contrast with adjoining fields planted with the sword suckers. When Professor Pittier made a visit to Costa Rica in 1907, three years after the beginning of the experiment, this field still appeared very distinctly superior to any of the adjoining areas.

Although no observations or tests were made to determine the resistance of these plants to disease, it is apparent even from this single experiment that commercial crops of bananas can be produced under conditions that would give a considerable measure of protection against disease. The resting tubers would be much less likely to convey diseases than the sword suckers, and could be much more easily disinfected. Some of the banana diseases that become very serious in old plantations appear to have little or no effect upon vigorous young plantations under favorable conditions. The more frequent replanting of bananas, every two or three years, is being advocated among the Jamaica planters, because the old stocks are thought to "run out" and become less vigorous, and also because the young plants can be brought into fruit with greater regularity.[a]

The possibility of producing a full and regular crop of large clusters of fruit by the use of tubers instead of sword suckers would also make it more feasible to use bananas in a rotation of crops, a policy which may prove to be as desirable in tropical cultures as in those of temperate regions, if a permanent use of the land is to be maintained. If the destructive policy of raising bananas for a few years and then abandoning the land continues to be followed in Central America, it will probably not require many decades to exhaust all the districts that are well suited to banana culture and at the same time readily accessible from the United States. In a few favored spots where soil conditions are ideal or where new soil continues to be deposited by floods of adjacent rivers, permanent cultures may be maintained, but in most places the prosperity of a banana plantation appears to have definite natural limits.

COMPARISONS OF DIFFERENT SYSTEMS AND TYPES OF BRANCHES.

One reason why dimorphism of branches has not received more attention is doubtless to be found in the fact that current botanical classifications of buds and branches do not provide adequate recognition for the different kinds of diversity shown by the branches, as among these tropical crop plants. The view generally stated or implied in text-books is that branches are to be divided, with reference to their methods of origin, into two principal kinds, axillary and adventitious. This compels us to infer that branches which do not come from the axils of the leaves must be regarded as adventitious, or to some extent irregular and abnormal.

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[a] "There is a growing tendency throughout the whole island to reduce the period of ratooning and to replant every two or three years, as it is found that by so doing the crops may be better timed for the American market, as after first ratoons the plants fruit somewhat irregularly." (See Stockdale, F. A., "The Question of a Banana Industry," Journal of the Board of Agriculture of British Guiana, vol. 3, no. 2, 1909, p. 81.)

It may be that the present series of facts of dimorphism will incline botanists as well as planters to take into account the normal and regular existence of branches which are neither truly axillary nor truly adventitious. It is as impossible to understand the habits of growth of the plants from the botanical standpoint as it is to find correct principles of cultivation and pruning without seeing that the same plant can produce two or more kinds of branch organs essentially distinct from each other in position, form, and function.

The different systems of branching have evidently been specialized on independent lines that could hardly be described on the basis of the usual classification of branches into two general classes—axillary and adventitious. There should be no implication that extra-axillary buds are of necessity adventitious, or that extra-axillary or adventitious buds are less important in any particular plant than axillary buds. There are no general relations between the position and the function, nor between the position and the time of appearance, nor yet between the time of appearance and the function. There are no general principles that apply to the dimorphic branches of all the different plants, nor do any two of them fully agree.

The extra-axillary branches of the coffee have the fruit-bearing functions of the axillary branches of Castilla, while the axillary uprights of coffee correspond functionally to extra-axillary uprights of Castilla. The axillary branches of Castilla must be considered as more definitely limited on the vegetative side than the extra-axillary branches of the other plants, in view of their temporary nature.

The specializations shown in the branches of the cotton plant are in some respects quite the opposite of those of the Central American rubber tree. The flowers and fruit of the cotton plant are borne on extra-axillary branches, those of Castilla on the axillary branches. The vegetative limbs of Castilla are all extra-axillary, while those of cotton are axillary. The axillary or fertile branches of Castilla are temporary, while the extra-axillary serve as permanent divisions of the main stem.

Coffee agrees better with cotton than with Castilla, since it is the axillary buds which give rise to the permanent, upright shoots. The extra-axillary branches of cotton and coffee are also alike in the bearing of fruit. Though extra-axillary in position they can hardly be called adventitious. Indeed, they are less adventitious than the axillary branches, for they are developed with far greater regularity. Extra-axillary buds in cotton and coffee seem to lack the power of remaining dormant. They do not appear to be present on young plants, and they are never added after the internode and its leaf or leaves have become mature. They are laid down with regularity as a part of each internode of the adult plant.

The extra-axillary buds, both in cotton and coffee, are developed with the same invariable regularity as the leaves themselves. They resemble adventitious buds only in the technical sense that their position is extra-axillary. Considered from the standpoint of the habit and functions of the plant, they are not more adventitious than the terminal or the axillary buds.

Before the young internode emerges from between the stipules of the coffee leaves, the three buds that give rise to the central axis and the two lateral branches can be found standing in a row with the axillary buds and only very slightly above them. Later on the three buds are pushed out nearly together, but the middle one soon leaves the other two behind. Strictly speaking, therefore, the extra-axillary branches of coffee arise from subterminal buds. After the branches are formed there is no internal indication of a joint or septum; the pith is quite continuous. Thus an internode of a main stem or an upright branch of coffee does not appear to be a simple cylinder, but a three-armed fork or trident.

The lateral branches of the coffee plant do not normally branch again, though they can be forced to do so by pruning. The secondary lateral branches are produced from sterilized flower buds, and have only the characters of laterals, never of uprights. Persistent pruning may exhaust all the buds capable of forming uprights and leave the tree a tangle of horizontal or drooping branches, apparently without the power to put forth any more uprights.

Branches of definitely limited possibilities of vegetative growth, like the fruiting branches of coffee and Castilla, may be considered as having intermediate functions between those of leaves and of ordinary types of vegetative branches. The leaves of Begonia and Bryophyllum, which produce plantlets from adventitious buds, and the leaf-like flower-bearing organs of Phyllanthus and Phyllonoma represent other intermediate stages between ordinary leaves and branches. The leaf-like branch organs of some of the relatives of asparagus, such as Ruscus and Semele, might be mentioned in the same connection. Even the tobacco leaf may develop a row of vegetative buds along the base of the midrib. The axillary branches of Castilla are as definitely deciduous as the leaves. The permanent branches of coffee are formed from axillary buds, while those of Castilla appear to be adventitious as regards the time of development, though they have definite positions.

Unless the different branch organs are to receive distinctive names in each of the different plants, it will be necessary to content ourselves with a few general terms that will enable us to indicate more directly the nature of these various kinds of branches. A primary distinction can be made as to whether a bud is laid down when the branch grows or is formed afterwards from unspecialized tissues of the bark. Buds that are not adventitious in the latter sense, but are formed with the growth of the internode to which they belong, might be called natal buds.

Adventitious branches are not supposed to have regularity of position, but such regularity should not be allowed to obscure their adventitious character if they are formed subsequent to the growth of the internode. The loss of the original axillary bud may be followed by the development of an adventitious axillary bud, as happens in coffee. Also the flower buds of coffee appear to be adventitious to a very considerable extent, and perhaps altogether so. With severe pruning, leafy branches may also be forced from the axils of the leaves of the fruiting branches long after the normal production of flowers and fruits would have ceased. This may be taken to show either that additional adventitious buds can be formed in the axils after the fruiting period is past, or that the axillary buds of the fruiting branches have previously remained dormant and not taken part in the production of flowers and fruit.

The fact that flower buds can be adventitious only emphasizes the more the absence of any general connection between origins, positions, and functions, for plants have always had flowers, or at least the essential sexual organs, even before they had the present specializations of their vegetative parts into branches and leaves. Flower buds could never be considered adventitious if we were to attach any functional sense to the term, but they appear adventitious with respect to the time and method of origin on the individual plant.

The terms axillary and extra-axillary are sufficient, perhaps, for the designation of the positions of the two kinds of buds on any particular plant, but as a general term extra-axillary is extremely indefinite. It groups together buds arising from internodes of the stem or trunk and those coming from the roots, as in the plum, pear, breadfruit, and sweet potato. It does not distinguish between the conditions to be found in coffee, where the extra-axillary branch is far above the axil, and in cotton and Castilla, where the extra-axillary branch is at the side of the axil.

Some might prefer to describe the cotton plant or the coffee tree as having two axillary buds, and thus avoid the tendency to confuse extra-axillary position with adventitious origin, but it is evident that no scientific object can be gained by applying the same name to things as different as the two kinds of branches. In the strictly mathematical sense only one bud could be axillary. No subsequent adventitious bud could be truly axillary. Yet to apply such a distinction to coffee would reduce it almost to an absurdity. Some of the fruit buds might be reckoned as axillary, but others closely adjacent would have to be considered as extra-axillary. The leafy branches which can be forced from these same axils by pruning would be axillary if they came out first, or extra-axillary if they followed a crop of flowers, a purely artificial distinction. Instead of attempting to establish too sharp a contrast between axillary and extra-axillary it would be better to admit a third and intermediate positional category of adaxillary branches, for those that stand close to the axil, as distinguished from extra-axillary branches that are distinctly separated from the axil.

If many buds arise simultaneously or successively from the axillary position, or as near to it as they can be placed, they might be termed coaxillary. The inflorescence branches of coffee could be described as coaxillary, and probably those of Cuscuta.[a]

In describing the functions of branches, distinctions are also to be observed. Some branches are completely vegetative and produce no flowers or inflorescences; some are completely reproductive, in the sense that they bear only floral buds. Between the two extremes a great multiplicity of intervening stages exists. Sometimes branches which normally bear fruit can be sterilized and rendered purely vegetative. In some plants all branches have equal vegetative potentialities; in others, as in coffee, cotton, and Castilla, the upright main stems are different from the lateral fruiting branches. In some plants these lateral branches can, in case of accident, become substitutes for upright stems; in others, they can furnish buds from which upright stems can arise; in still others, the lateral branches are without the power to replace the main steam.

The existence of two or more buds in or about the axil of a leaf is known, of course, in many plants and has been recognized by writers on plant morphology, but definite specializations of positions and functions have not received the attention required by the agricultural importance of such facts. As long as no difference of function has to be considered, additional buds can be considered as mere substitutes or accessories of the true axillary bud. Thus Pax[b] recognizes what he calls "beisprossen," or accessory shoots, and subdivides these into two classes: (1) Serial shoots, if they arise one above the other, and (2) collateral shoots, if they appear side by side.

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[a] Dr. C. E. Bessey, in a paper on the adventitious inflorescence of *Cuscuta glomerata*, stated that the examination of young plants shows that the inflorescence is developed from numerous crowded adventitious buds and not by the repeated branching of axillary flowering branches, as commonly stated. Science, vol. 4, 1884, p. 342.

[b] Pax, F. Allgemeine Morphologie des Pflanzen, p. 16.

Until more general studies and classifications of methods of branching can be made it seems best to retain the ordinary designations of uprights, laterals, etc., especially in connection with plants to which these terms have already been applied. All that can be attempted at present is to indicate the varied relations between the different positions and functions of branches in the plants that have been studied.

SUMMARY OF TYPES OF BRANCHES.

The characters of the different kinds of branch individuals of cotton and the other plants with which it has been compared can be defined or briefly described as follows.

BRANCHES OF COTTON.

(1) *Axillary limbs.*—Natal axillary branches which never produce flowers, but are like the main axis of the plant in forming at each node an axillary vegetative bud and an adaxillary bud that may give rise to a vegetative or a fertile branch.

(2) *Fertile branches.*—Natal adaxillary branches which produce a flower bud on each internode, in an adaxillary position, and an axillary vegetative bud.

(2a) *Vegetative branches.*—Natal adaxillary branches which have the same form and functions as the main stem or the axillary limbs.

In varieties that have normally complete dimorphism of the branches, axillary buds give rise to vegetative branches only. Adaxillary buds can produce fertile branches or vegetative branches, except on fertile branches, where they produce flowers.

The cotton flower is always solitary, except in cases of fasciation, that are rather common in cluster varieties. Being extra-axillary, the flower is not directly subtended by a leaf or a bract, though there is a whorl of three bract leaves at the end of the simple peduncle.

BRANCHES OF CASTILLA.

(1) *Temporary branches.*—Natal axillary branches producing leaves and inflorescences; short lived and deciduous; not able to serve as main stems.

(2) *Permanent branches.*—Adventitious adaxillary or extra-axillary branches, bearing leaves and temporary branches, but no inflorescence branches; serving as permanent divisions of the main stem.

(3) *Inflorescence branches.*—Natal coaxillary branches borne on the temporary branches in clusters of four male inflorescences or two male and one female.

BRANCHES OF COFFEE.

(1) *Upright branches.*—Natal axillary branches not producing inflorescence branches; serving as equivalents of the main stem.

(2) *Lateral branches.*—Natal extra-axillary branches attached to the bases of the internodes of the main stem or of the upright branches. Lateral branches produce leaves, inflorescence branches, and secondary laterals, but are unable to replace the main stem.

(2a) *Secondary lateral branches.*—Adventitious branches arising from axillary buds of the lateral branches. They are inflorescence branches pushed into vegetative growth by severe pruning. In form and function they agree with the lateral branches.

(3) *Inflorescence branches.*—Natal and adventitious coaxillary branches borne in clusters on lateral and secondary lateral branches.

BRANCHES OF CACAO.

(1) *Upright branches.*—Probably adventitious extra-axillary branches, bearing long-petioled leaves and able to produce branches of all three kinds and to become permanent parts of the main stem.

(2) *Whorled branches.*—Natal axillary branches produced in whorls and terminating upright branches. Whorl branches bear short-petioled leaves, lateral branches, and inflorescence branches, but are unable to replace the main stem.

(2a) *Lateral branches.*—Natal axillary branches produced by whorled branches and having the same functions; not producing whorled branches or main stems.

(3) *Inflorescence branches.*—Adventitious extra-axillary branches arising from the mature wood of the main trunk and the whorled and lateral branches, without power to replace the main stem or the vegetative branches.

BRANCHES OF THE BANANA PLANT.

(1) *Sword suckers.*—True branches of the rhizome that arise from subterranean buds, develop large bulbous bases, and put forth narrow leaves when young.

(2) *Broad-leaved suckers.*—Offshoots adapted for separate vegetative propagation, arising from superficial buds and bearing broad-bladed leaves while still young.

The relations between the positions and the functions of the branches of the four woody plants are summarized as follows:

Summary of the classification of branches.

Description.	Cotton.			Castilla.		Coffee.			Cacao.	
	1.	2.	2a.	1.	2.	1.	2.	2a.	1.	2.
Origin:										
Natal buds	×	×	×	×	......	×	×	......	......	×
Adventitious buds	......	......	......	......	×	......	......	×	×	......
Position:										
Axillary	×	......	......	×	......	×	......	×	......	×
Adaxillary	......	×	×	......	×	......	......	......	......	......
Extra-axillary	......	......	......	......	×	......	×	......	×	......
Reproductive function:										
Fertile	......	×	......	×	......	......	×	×	×	×
Sterile	×	......	×	......	×	×	......	......	......	......
Vegetative function:										
Able to form main stems	×	......	×	......	×	×	......	......	×	......
Not able to form main stems	......	×	......	×	......	......	×	×	......	×

CONCLUSIONS.

Definite dimorphism of branches exists in at least five important tropical crop plants—cotton, coffee, cacao, the Central American rubber tree (Castilla), and the banana. Each normal plant produces two kinds of branches, with regular differences of form and function.

The factor of branch dimorphism must be taken into account in the scientific study of the structure and habits of all these plants, as well as in the breeding and adaptation of varieties. Systems of cultivation and pruning must likewise be planned with reference to the habits of branching.

In each species there is a definite relation between the functions of the branches and their positions or places of origin on the internodes, but there is no general relation of position to function that applies to all the species, or even to any two of them. It is necessary to consider each plant separately in order to understand the agricultural importance of the dimorphism of the branches.

In the cotton plant the branches that arise in the axillary position have vegetative functions only, like the main stalk. The branches that produce the flowers and fruit are extra-axillary; that is, they arise at one side of the axillary branch or bud. Branches with the vegetative form and functions may replace the fruiting branches, in the extra-axillary position, but no normal fruiting branches develop in the axillary position.

The definite differentiation of the two kinds of branches represents a normal condition in all the types of cotton that have been studied from this point of view. Intermediate forms of branches are accompanied by abortion of flower buds and other abnormalities.

The substitution of additional branches of the vegetative form for the fruiting branches is a frequent occurrence in imported types of cotton. The plants regain their normal fertility when the normal relations of the branches are restored. This readjustment of the habits of branching represents one phase of the process of acclimatization.

The dimorphism of the branches is also a factor in the problem of weevil resistance, since the development of larger or more numerous vegetative branches tends to render the crop late. Early crops usually suffer less injury from the weevils.

In the Central American rubber tree (Castilla) the axillary branches do not share all the functions of the main stalk or trunk of the tree. The axillary branches bear the flowers and fruit, but are shed after a few seasons. The permanent branches always arise from extra-axillary positions and usually do not begin to develop until the tree is several years old.

The self-pruning habit of the Central American rubber tree is an important cultural advantage. Only an occasional tree requires pruning, and then only to correct accidents or abnormalities.

In the coffee tree only vegetative branches, or uprights, like the primary trunk, are produced from the true axillary buds. All the fertile branches, or laterals, have extra-axillary positions above the true axillary branches. Lateral branches can not produce uprights, nor can new laterals be produced from old uprights.

As the crop is borne only on young wood of lateral branches, a vigorous growth of lateral branches must be maintained if good crops are to be secured. New uprights must be formed to produce new laterals, or laterals may continue to grow and subdivide if the growth of uprights is prevented by pruning. Failure to take the dimorphism of the branches fully into account in the work of pruning often results in serious injury to coffee plantations. The practical value of the different systems of pruning the coffee tree depends on local conditions of climate and soil, as well as upon the quality and cost of the labor supply.

In the cacao tree fruit twigs may be borne on all parts of the old wood, including that of the main trunk, but there are two types of vegetative branches. The upright growth of the trunk takes place by a series of shoots, each of which is terminated by a whorl of three to six branches. A new upright shoot arises from the side of another upright, not from a whorl branch.

The natural habit of growth of the cacao tree, by a succession of whorls, is very undesirable in plantations, and can be avoided by judicious pruning of the young trees to induce them to develop their crowns from some of the members of the first whorl of branches, instead of allowing them to produce a succession of uprights and whorls.

The banana plant also produces two forms of suckers or offshoots, corresponding to the dimorphic branches of the woody species. The so-called sword suckers represent true permanent branches of the rhizome. They arise from large subterranean shoots nourished by the parent plant, and bear at first only narrow, sword-shaped leaves.

The so-called broad-leaved suckers arise as relatively small shoots from near the surface of the ground. Even in the young stage they produce broad-bladed leaves like those of the adult plant, and are adapted for separate propagation.

Dormant tuber-like suckers of the broad-leaved type are formed on uprooted rhizomes, and constitute a readily portable form of propagating stock from which vigorous and productive banana plants may be grown. The use of such tubers may render it possible to produce bananas under a system of rotation with other tropical crops.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Abnormal branches and involucres in the Dale variety of Egyptian cotton, where such abnormalities are especially common, though they occur also in other Egyptian varieties, as well as in Upland cotton. The figure near the upper left-hand corner of the plate represents a normal involucre of Egyptian cotton seen from the side, so that only one of the three bracts is shown. The figure at the top of the plate and that with the largest leaf immediately below represent the first stages of transformation from leaves to bracts, with the stipules enlarged, the petiole shortened, and the blade reduced in size, but retaining the texture of a normal leaf. Other figures show intermediate conditions, with the petiole suppressed, the blade more reduced and united with the stipules, and the texture becoming the same as in an ordinary involucral bract. The lower right-hand figure shows an involucre with only two bracts, the upper bract still of the intermediate form, while the lower is nearly normal, except at the base, where there is an unusually large bractlet. (Natural size.)

Plate II. Bolls produced on short axillary branches of the Dale variety of Egyptian cotton. The long stalks of these bolls represent the fused joints of rudimentary branches, as shown by the presence of small bractlike leaves and stipules. In the figure on the left-hand side of the plate there is a bractlike organ in the position that would be occupied by a leaf on a normal fruiting branch. In the figure at the bottom of the page this organ is reduced to the size of a stipule, while on other stalks it is entirely absent. One stalk is distinctly jointed and bears two bolls in a double involucre, an example of fasciation. The right-hand figure shows an abortive fruiting branch ending in a single leaf with enlarged stipules, and a simple axillary branch bearing a normal boll. (Natural size.)

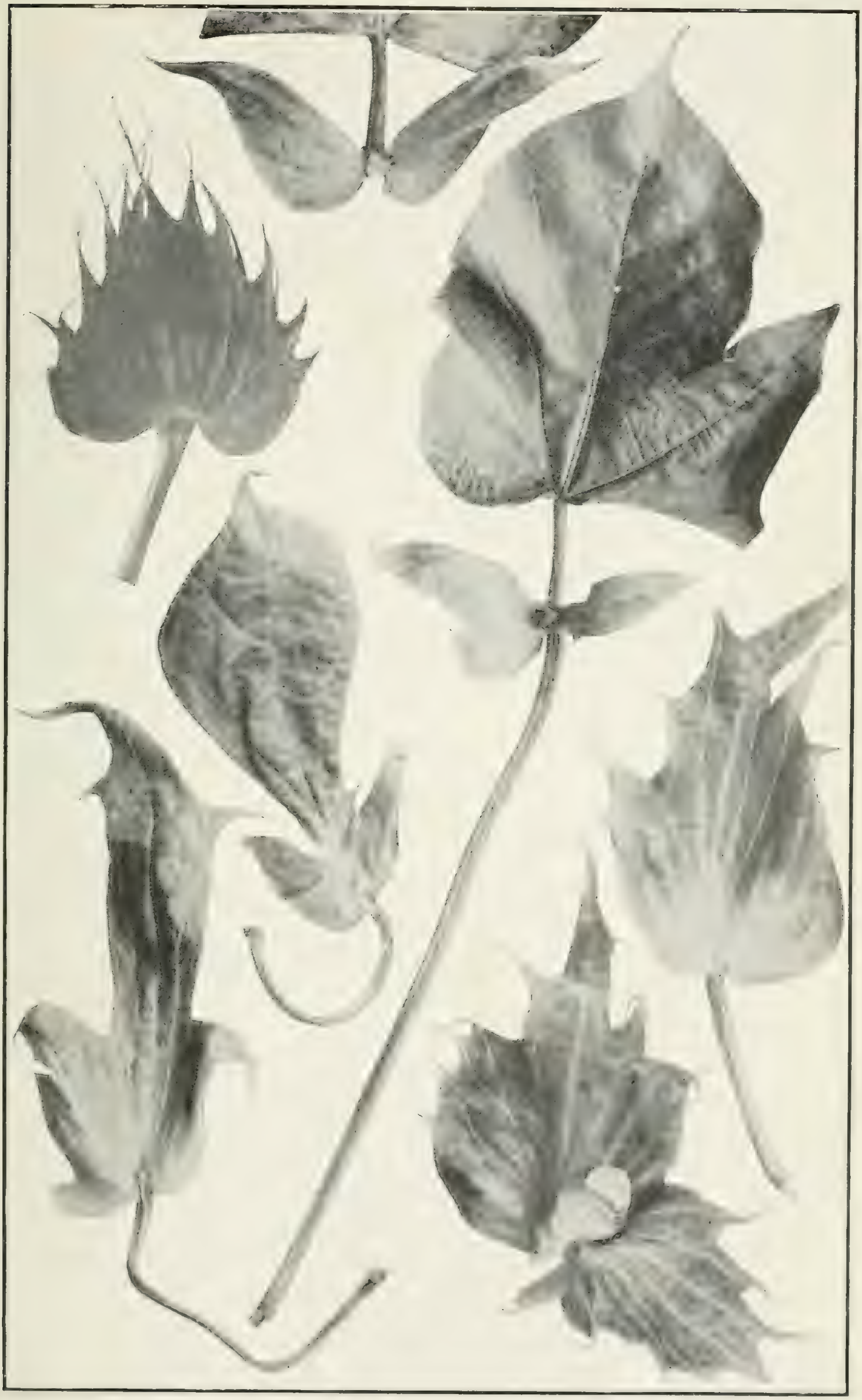
Plate III. Part of a Maragogipe coffee tree on the Sepacuite plantation, Alta Vera Paz, Guatemala, showing three upright branches bearing numerous horizontal lateral branches. The leaves of this variety are larger, heavier, and more inclined to be crumpled than those of the ordinary Arabian coffee. (Greatly reduced.)

Plate IV. The left-hand figure shows one internode of a very young upright and a complete internode of one of its lateral branches, projecting underneath the right-hand figure. The right-hand figure shows an older upright where pruning has forced the growth of two new upright branches, with short basal internodes, arising below the bases of the nearly horizontal lateral branches. (Natural size.)

Plate V. A diseased condition of the lateral branches of Arabian coffee in eastern Guatemala, where the branching of the laterals has been forced by persistent pruning. (Natural size.)

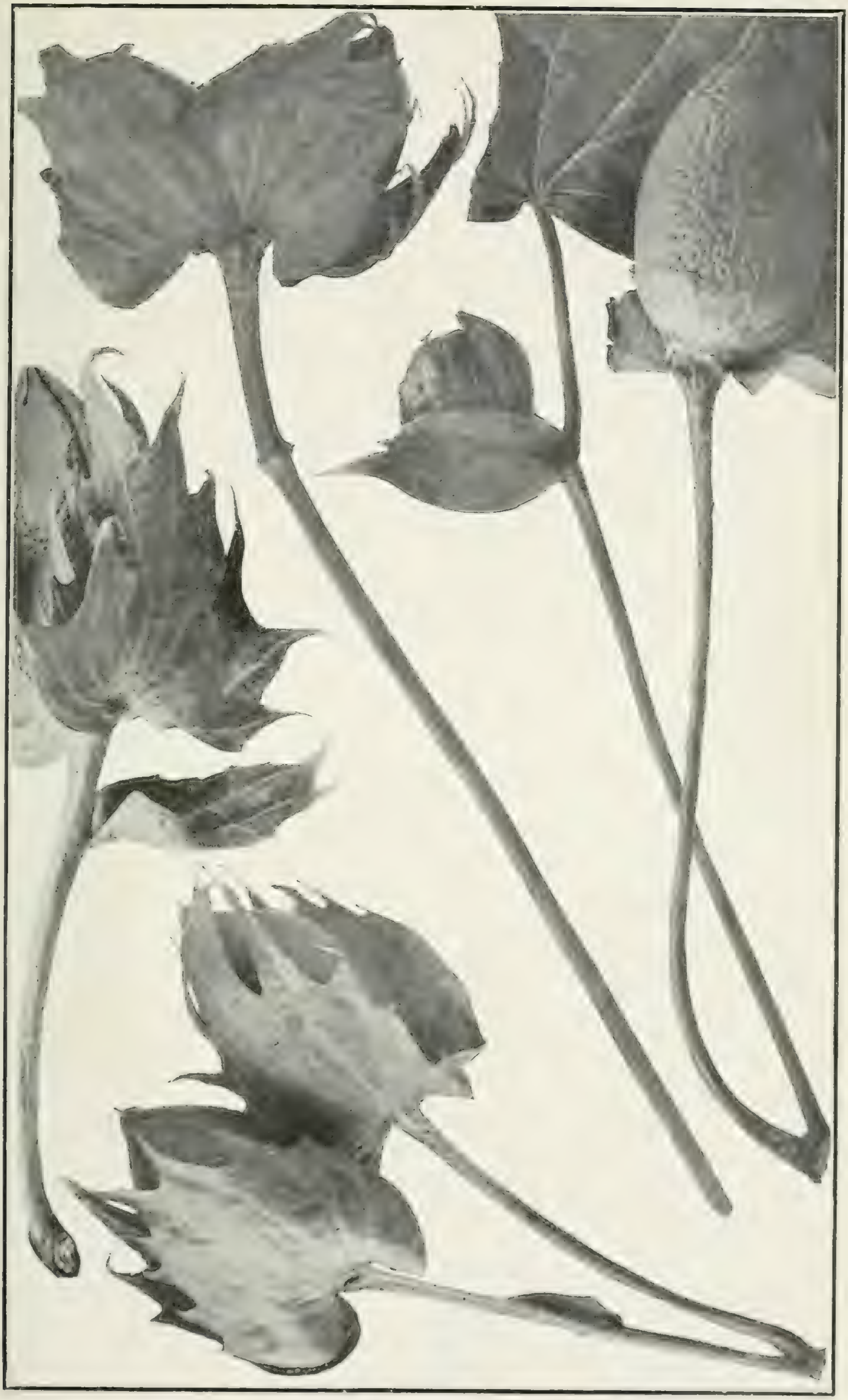
Plate VI. A young cacao tree on the Trece Aguas plantation, Alta Vera Paz, Guatemala, showing the normal method of producing branches in whorls. The whorled branches do not give rise to upright shoots, which develop from the side of the old uprights underneath the whorls. (Greatly reduced.)

Plate VII. Fig. 1.—Petioles of leaves from uprights of cacao. The upright branches of the cacao produce leaves with the long petioles (left-hand side of the figure). The whorled branches produce leaves with short petioles (right-hand side of the figure). (Natural size.) Fig. 2.—Section through the rhizome of a banana plant showing that sword suckers are true branches of the rhizome, unlike the broad-leaved suckers that arise from buds near the surface of the ground. (Greatly reduced.)



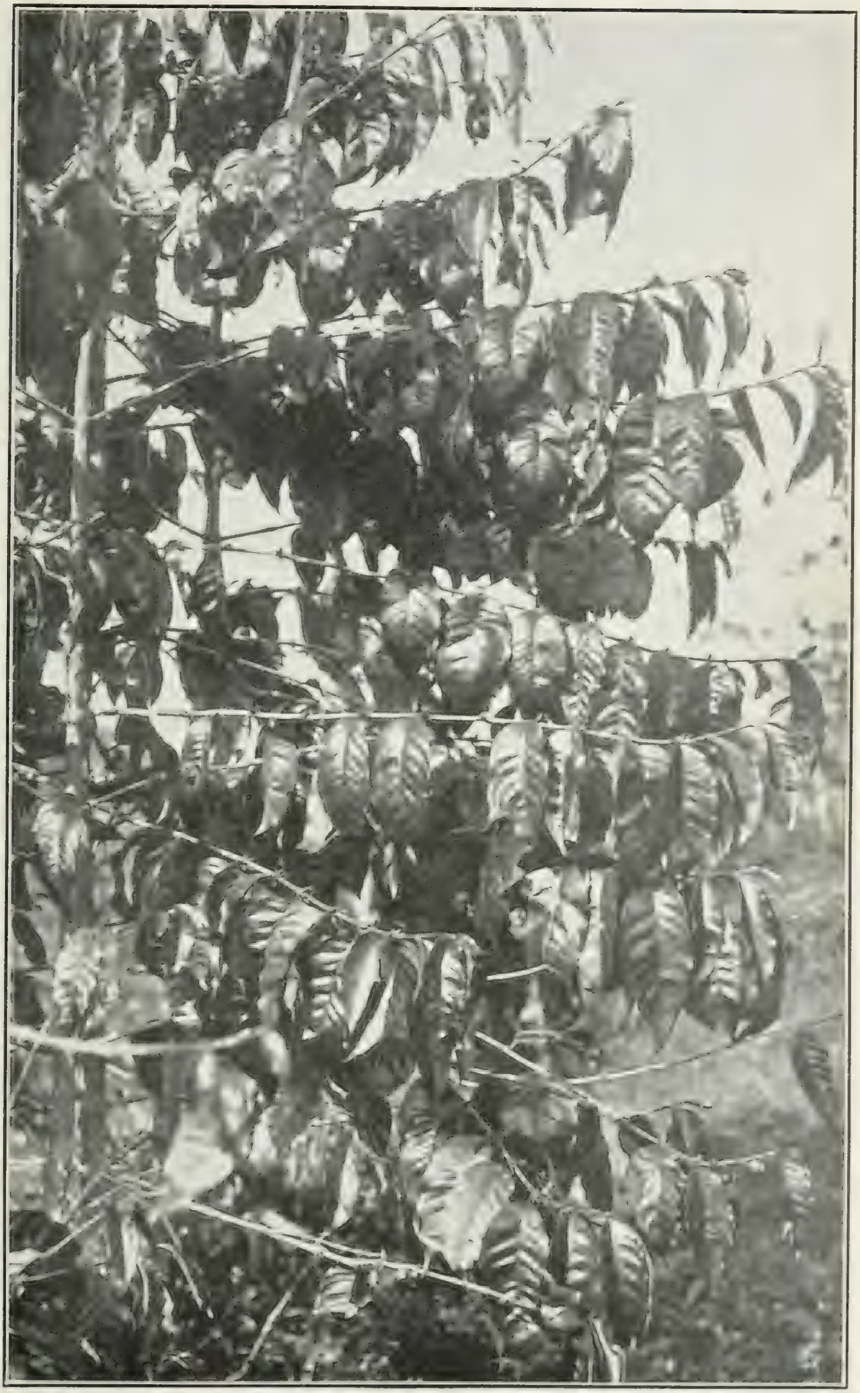
ABNORMAL BRANCHES AND INVOLUCRES OF EGYPTIAN COTTON.

[Natural size.]

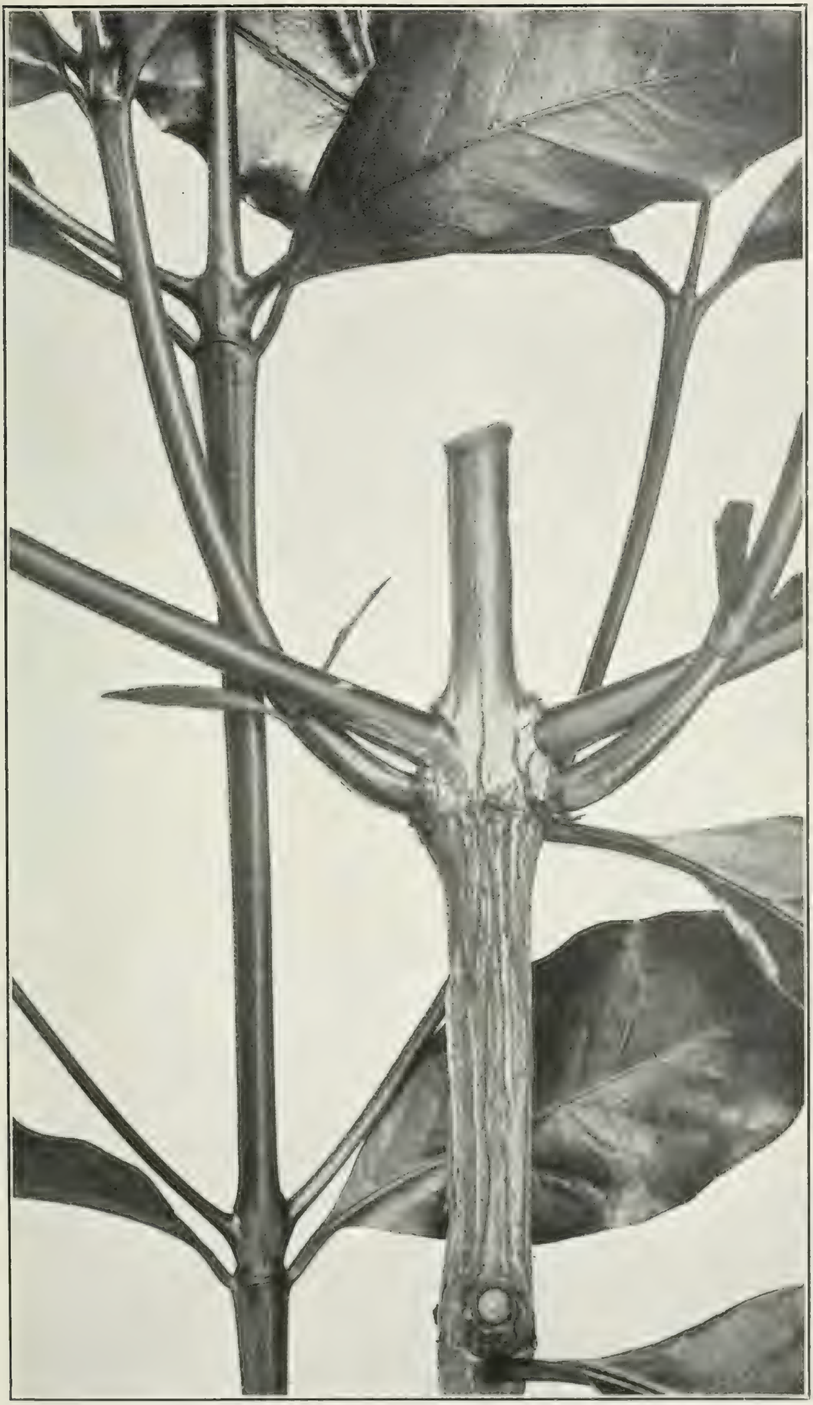


BOLLS PRODUCED ON SHORT AXILLARY BRANCHES OF EGYPTIAN COTTON.

[Natural size.]

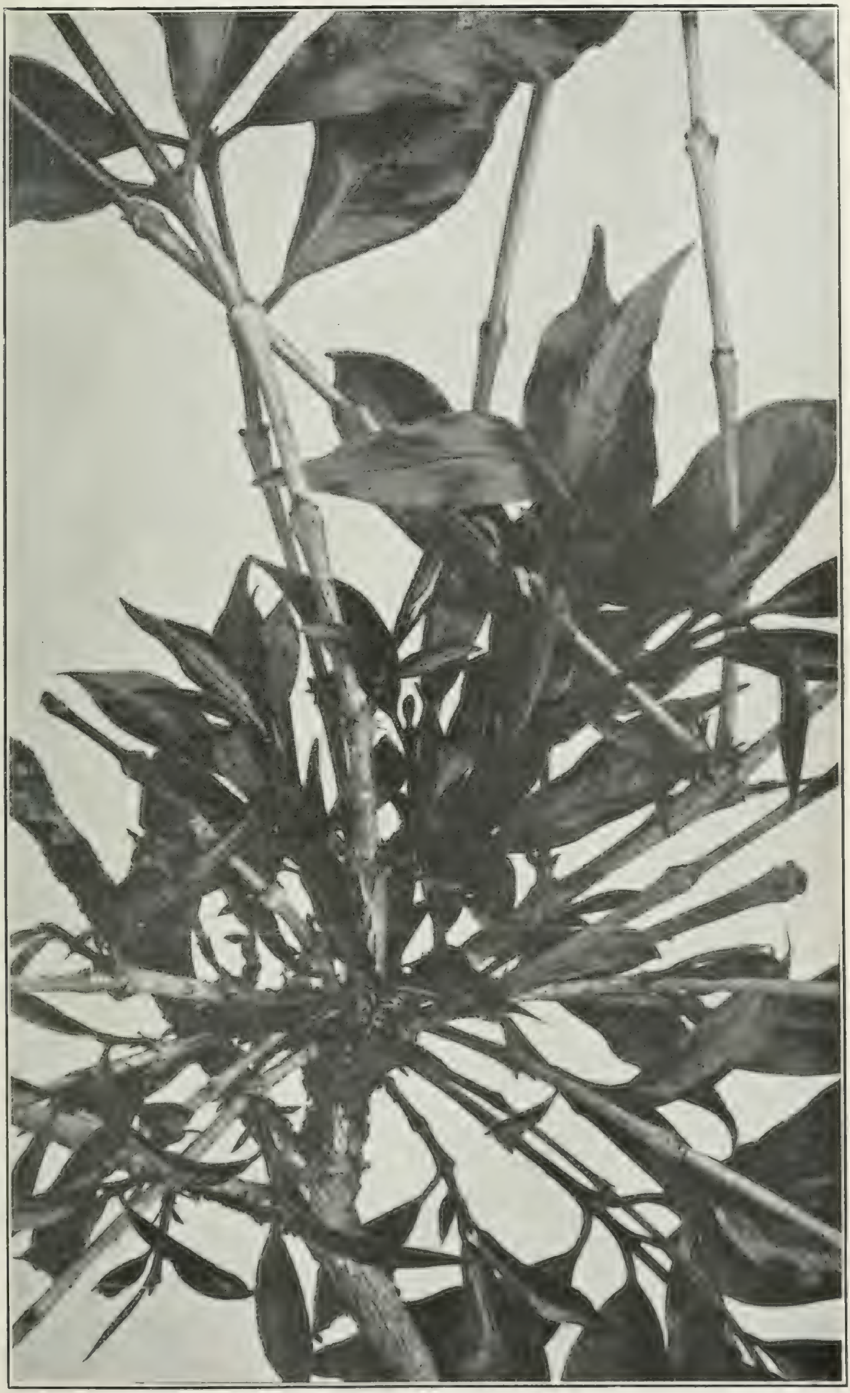


COFFEE TREE, MARAGOGIPE VARIETY, SHOWING THREE UPRIGHT BRANCHES BEARING NUMEROUS LATERAL BRANCHES.

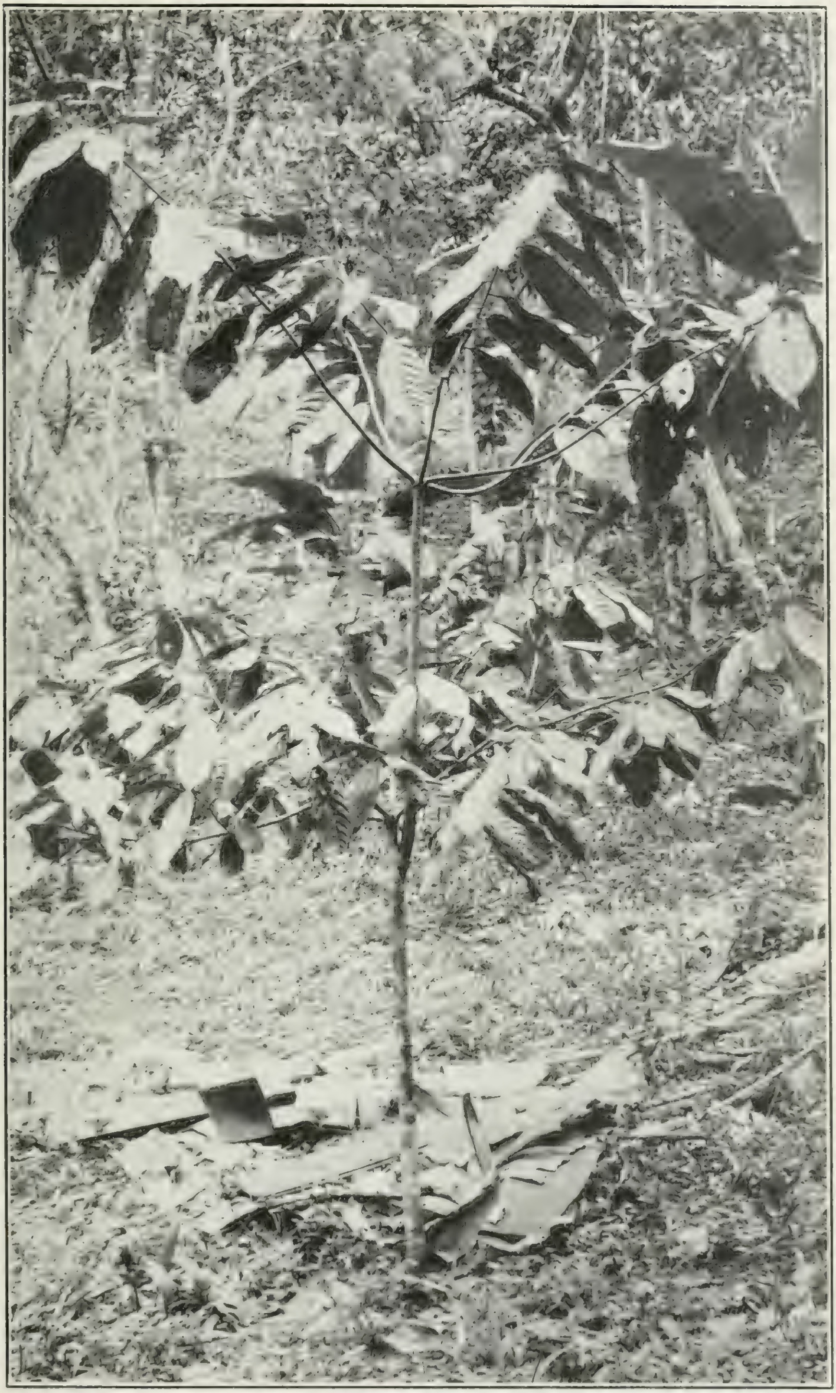


UPRIGHT AND LATERAL BRANCHES OF COFFEE.

[Natural size.]



ABNORMAL FORMATION OF LATERAL BRANCHES OF COFFEE.



A YOUNG CACAO TREE WITH TWO WHORLS OF BRANCHES.

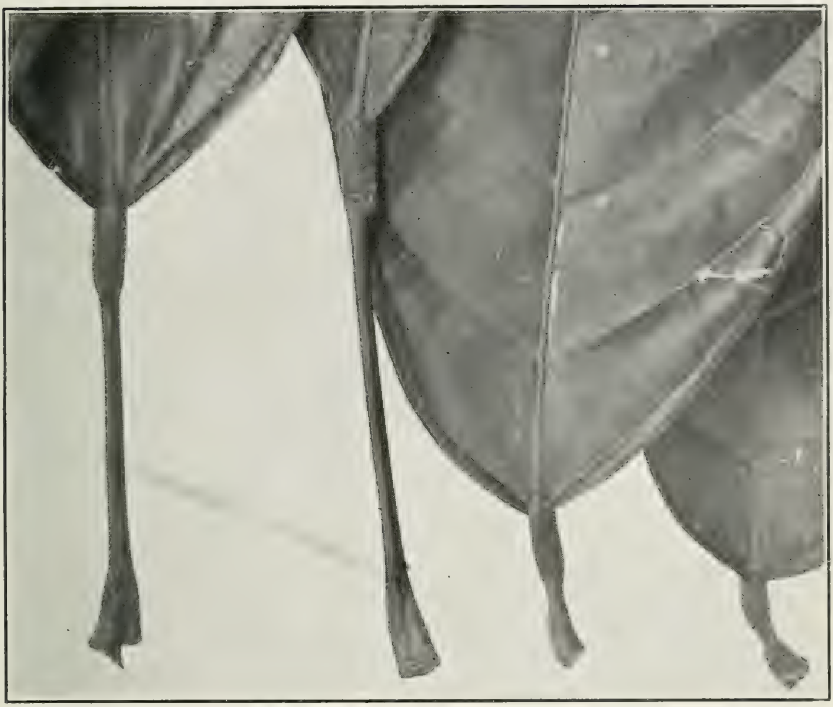


FIG. 1.—PETIOLES OF LEAVES FROM UPRIGHTS AND WHORL BRANCHES OF CACAO.

[Natural size.]

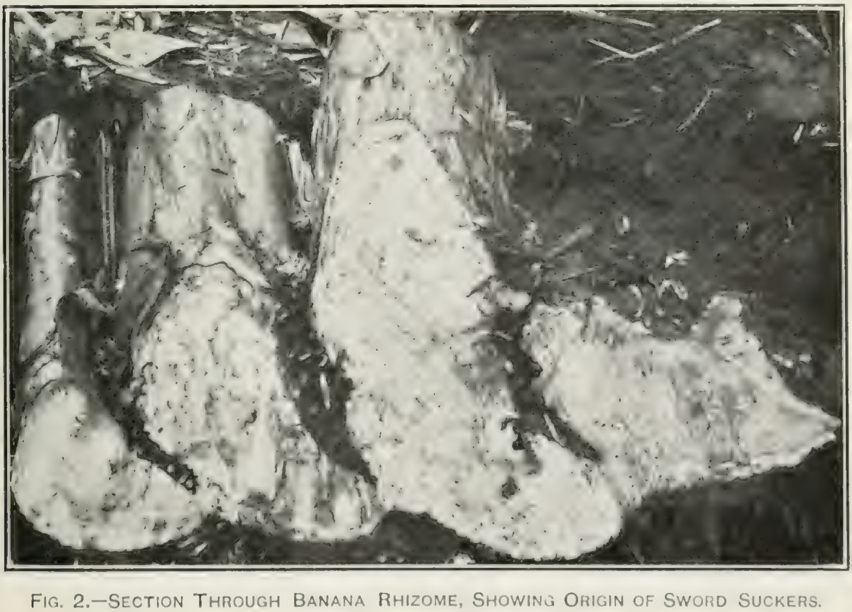


FIG. 2.—SECTION THROUGH BANANA RHIZOME, SHOWING ORIGIN OF SWORD SUCKERS.

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- Acclimatization of cotton. *See* Cotton, acclimatization.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 199.
B. T. GALLOWAY, *Chief of Bureau.*

THE DETERMINATION OF THE DETERIORATION OF MAIZE, WITH INCIDENTAL REFERENCE TO PELLAGRA.

BY

O. F. BLACK AND C. L. ALSBERG,
CHEMICAL BIOLOGISTS, DRUG-PLANT, POISONOUS-PLANT,
PHYSIOLOGICAL, AND FERMENTATION INVESTIGATIONS.

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DRUG-PLANT, POISONOUS-PLANT, PHYSIOLOGICAL, AND FERMENTATION INVESTIGATIONS.

SCIENTIFIC STAFF.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 20, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 199 of the series of this Bureau the accompanying manuscript entitled "The Determination of the Deterioration of Maize, with Incidental Reference to Pellagra," by Mr. Otis F. Black and Dr. Carl L. Alsberg, Chemical Biologists, which has been submitted for publication by Dr. Rodney H. True, Physiologist in Charge of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations, of the Bureau of Plant Industry.

As a necessary preliminary step in the investigation of the alleged relation between spoiled corn and pellagra the authors of this paper have made a critical study of the methods of detecting products of deterioration in corn and corn meal. The recent recognition of pellagra in the United States has emphasized the fact that there is a lack of such information in a form available for English readers and has brought about a considerable demand for it. The accompanying paper deals critically with the value of methods employed in foreign countries and contains experimental data bearing upon their application to conditions in this country. The work constitutes a first step in the study of the constituents present in corn and the possible production of toxic substances by deterioration.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—609.

THE DETERMINATION OF THE DETERIORATION OF MAIZE, WITH INCIDENTAL REFERENCE TO PELLAGRA.

INTRODUCTION.

The recent recognition of cases of pellagra in this country, principally in the Southern States, and the supposed connection of the disease with the consumption of unsound corn[a] have called attention to the lack of methods by which to test the fitness of corn and corn meal for human consumption. There is every reason to believe that sound corn is a most wholesome food. Whether corn that has been heated, fermented, or molded is equally safe is another question. That it is unsafe and the cause of pellagra is so firmly believed in Italy and the Austrian Province of the Tyrol that the Governments of these countries have enacted stringent laws regulating the quality of corn and corn meal which may be sold or imported.[b] The possibility that spoiled corn may possess poisonous qualities seems to have passed unnoticed in this country.

Indeed, it is found that with the exception of such work as that of Osborne [c] and others upon the proteins, little work has been done upon the chemistry of corn. Most investigators have contented themselves with the determination of protein, carbohydrate, fat, and ash. Some have also studied certain of the simpler constants of these groups of substances. The attempt to disentangle the mixture of complex substances of which the corn seed, like any other living thing, is composed has hardly begun. The investigators of southern Europe who had in the alleged connection between pellagra and corn a great incentive to undertake this work have not done so. In southern Europe, however, much attention has been paid to the toxicity of spoiled corn, if not to the chemistry, and the relevant literature is very large.

---

[a] The term "corn" is a general one, usually applied to the chief cereal crop of a country. It is therefore not necessarily applied everywhere to the same cereal. Thus, in England, it is applied to wheat, and in the United States to maize (Indian corn). The terms Indian corn, maize, and corn will be used interchangeably in this paper.

[b] Bollettino Ufficiale del Ministero d'Agricoltura, Industria, e Commercio, Rome, new series, vol. 4, no. 4, October, 1902, pp. 663–666.

Gesetz und Verordnungsblatt für die gefürstete Grafschaft Tyrol und das Land Vorarlberg, 1904, no. 12, p. 57.

[c] Chittenden, R. H., and Osborne, T. B. A Study of the Proteids of the Corn or Maize Kernel. American Chemical Journal, vol. 13, 1891, pp. 453 and 529, and vol. 14, 1892, p. 20.

Osborne, T. B. The Amount and Properties of the Proteids of the Maize Kernel. Journal of the American Chemical Society, vol. 19, 1897, p. 525.

Osborne, T. B., and Harris, I. F. The Specific Rotation of Some Vegetable Proteins. Journal of the American Chemical Society, vol. 25, 1903, p. 842.

Osborne, T. B., and Clapp, S. H. Hydrolysis of the Proteins of Maize. American Journal of Physiology, vol. 20, 1908, p. 477.

Osborne, T. B., and Harris, I. F. Nitrogen in Protein Bodies. Journal of the American Chemical Society, vol. 25, 1903, p. 323.

It is not the object of this paper to discuss the question whether pellagra is due to eating spoiled maize. The position taken is that whatever may ultimately prove to be the cause of pellagra the consumption of spoiled maize is undesirable. Even if spoiled maize should ultimately be proved to have nothing whatever to do with pellagra, its consumption would still remain decidedly objectionable for the same reasons that would apply to any other form of spoiled food. Here the economist, the hygienist, and the agriculturist meet upon common ground. If the hygienist should condemn corn as corn, it would react upon the agriculturist by narrowing the market for the country's chief crop. It is therefore of the utmost importance to the agriculturist that the deterioration of corn be investigated in all of its bearings in order that he may learn to avoid the causes of the spoiling of corn and that the consumption of spoiled corn by man may be limited. Ultimately this will be to the interest of all classes, whether growers, middlemen, or consumers. To bring about this result it must be possible to detect deterioration in corn. This is not always easy, even for unground corn. By drying moldy corn, moving it about in an elevator,[a] thereby polishing off the mold which covers the individual kernels, and by mixing it with sound corn it is possible to render the detection of spoiled corn difficult. When it is a question of meal made from spoiled corn or meal made from sound corn but spoiled after milling, the matter becomes even more difficult. In such cases special methods are necessary. Some methods for this purpose have been devised in Italy[b] and Austria.[c]

As far as known no work along these lines has been published in this country or, indeed, in the English language. To fill this gap by a critical study of the methods used in Europe and where possible to add to them is the object of the present paper. It is hoped to give criteria which will enable manufacturers of human food, public health officers, the directors of hospitals, of insane asylums, of penal institutions, and others to judge of the quality of corn and corn meal.

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[a] This process is called "running" and is a common treatment, as it aerates and thus helps to dry the corn.

[b] Antonini, G. Atti del Terzo Congresso Pellagralogico Italiano, September, 1906. Udine, 1907, p. 70.

[c] Schindler, J. Anleitung zur Beurteilung des Maises und seiner Mahlprodukte mit Rücksicht auf ihre Eignung als Nahrungsmittel. Verfaszt über Veranlassung der königlich kaiserlichen Statthalterei in Innsbruck. Innsbruck, 1909.

In Italy and Austria, where the Governments carefully control the quality of corn, suspected corn is examined by skilled government experts. In this country, where the examinations will be made in most cases only upon the initiative of private individuals, many of the tests applied abroad would often be of little service because they require a considerable degree of chemical or bacteriological skill. What seems to be needed in this country is some adequate test of so simple a character that it may be applied by the manufacturer, the health officer, or the consumer in determining whether products or purchases are fit for human food.

Such a test is thought by the writers to be the determination of the acidity of corn. This is a well-known test in both Italy and Austria, where much stress is laid on its importance. In this work it has been found the most reliable means of distinguishing good from bad corn. All corn is somewhat acid, not necessarily to the taste, but to chemical reagents. Since the spoiling of corn is due to fermentation processes in which acids are among the products, the extent to which this deterioration has progressed can be measured by the amount of acid present. It becomes necessary then only to fix a standard of acidity above which corn should be considered unfit for food.

It is desired at this point to avoid creating a misunderstanding. It is desired most carefully to avoid producing the impression that all fermented, heated, moldy, or otherwise spoiled corn is necessarily dangerous to man. This would hardly be in accord with the facts. It is, however, quite generally believed by the majority of investigators that much of this sort of corn is injurious. As long as no more definite information exists it seems the sane and conservative course to bar as far as possible damaged corn from human consumption.

The remainder of this paper will be divided into two parts, the first giving a description of the method of determining the acidity of corn and the second and longer part designed for the use of those more or less skilled in chemical manipulations and giving a critical presentation of various methods of examination.

PART I.—METHOD OF DETERMINING THE ACIDITY OF CORN.

Apparatus necessary.

One graduated burette.

One or more 50 cubic centimeter graduated glass flasks fitted with ground-glass stoppers.

One or more 5-inch glass funnels.

One filter stand or some appliance for holding funnel while filtering.

Three-inch filter papers, preferably folded filters.

One or more 25 cubic centimeter graduated glass cylinders.

If whole corn is to be examined, a mill is necessary—a drug or coffee mill will do.[a]

Reagents necessary.

Neutral alcohol. Such alcohol may be obtained from dealers in fine chemicals. If no neutral alcohol is at hand, it may be readily prepared by the distillation of the ordinary 95 per cent alcohol with the addition of unslaked lime. A few lumps of quicklime are put in a still or retort of copper or iron; the alcohol is poured in and the still connected with a water-cooled condenser. The so-called Liebig condenser is good for this purpose. The connections may be made with suitably bent glass tubes and cork or rubber stoppers. A receiving vessel is placed under the open end of the condenser to catch the alcohol. The still or retort is then heated with a nonluminous flame till the greater part of the alcohol has boiled over. All the alcohol can not be recovered because of the danger of burning the still. An ordinary kerosene can may be used as a still, the spout of the can being connected with the condenser. If no metal vessel suitable for use as a still is at hand, a glass distilling flask may be secured from a dealer in chemical apparatus. It is best to use those made of Jena glass. The glass must not be heated directly, but must be heated over a water bath in the manner of a double boiler. To accomplish this it is immersed up to the beginning of its neck in some sort of kettle filled with water. The heat is then applied to the kettle. The flask is touched only by the boiling water. Care must be taken that the flask does not break, for then there is danger of setting the alcohol on fire. A fire of this kind is best put out by smothering it with sand, a small keg of which should be kept handy.

A solution of phenolphthalein as indicator.

Distilled water.

Twentieth normal caustic alkali (NaOH or KOH). This, too, may be purchased from dealers in fine chemicals. Only small quantities should be purchased or made at a time, as it deteriorates in a month or two, even if tightly stoppered, when it should be replaced with fresh solution.

Procedure.

If the sample to be tested is whole corn it must first be ground until all of it can be passed through the 20-mesh sieve. For this purpose a fair sample should be made, taking it from different parts of the lot—the bottom as well as the top. The sample should not be too small. It should consist of at least 500 kernels. If it is meal no further grinding is necessary, but the sample should be a mixed one, consisting of portions taken from different parts of the sack. Ten grams of the thoroughly mixed sample are weighed out and transferred to a 50 cubic centimeter graduated flask fitted with a ground-glass stopper. The flask is then filled to the 50 c. c. mark with neutral alcohol of a strength of 85 per cent by volume. After the addition of the alcohol the flasks are allowed to stand for twenty-four hours at room temperature with an occasional shaking. At the end of that period a dry filter paper is placed in the glass funnel and the stem of the funnel brought over the 25 cubic centimeter cylinder. Then the clear liquid in the 50 c. c. graduated glass flask is poured into the dry filter and collected in the graduated cylinder. When this is filled to the 25 c. c. mark, the contents are transferred to a small flask or beaker.

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[a] A satisfactory mill is depicted by C. S. Scofield, in "The Commercial Grading of Corn," Bulletin 41, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1903, pl. 2. For whole corn a sieve made of bolting cloth with 20 meshes to the inch will also be required. If meal only is to be examined, both the mill and the sieve may be dispensed with.

The alcohol adherent to the inside of the cylinder is rinsed into the beaker with a little distilled water. From 100 to 150 c. c. of distilled water and a few drops of the phenolphthalein solution are then added to the liquid. The burette, which must be clean and dry, is filled to the zero mark with the twentieth normal alkali solution and the alkali allowed to run drop by drop into the beaker, the contents of which are continually stirred, until the first permanent pale-pink coloration of the whole liquid appears. The number of cubic centimeters run into the beaker is then read off on the burette. The number of cubic centimeters twentieth normal alkali solution used, multiplied by 10, gives the acidity of 1,000 grams (1 kilogram) of corn in terms of cubic centimeters, normal alkali. The results given below under the head of acidity are calculated on this basis. It is to be noted that on the addition of the 100 to 150 c. c. of distilled water to the 25 c. c. of alcoholic extract, some zein (the alcohol-soluble protein found in corn) is precipitated, giving a cloudy appearance to the solution; but this cloudy appearance wholly or partly disappears on the addition of alkali from the burette, so that the pink coloration which marks the end point of the operation is quite obvious.

Having determined the acidity of the corn sample in terms of cubic centimeters of normal alkali, the question that next arises is whether the acidity found is that of good corn or is greater than it should be. As will be seen by reference to Part II of this paper, it has been found that the acidity number of sound corn ranges from 13 to 25; i. e., it required from 13 to 25 cubic centimeters of normal alkali to neutralize the extract from 1,000 grams (1 kilogram) of sound corn. It is necessary, however, to allow for a certain amount of variation in the corn, so that 30 cubic centimeters may be fixed upon as a safe limit. This is the limit adopted by Schindler,[a] the Austrian authority. The writers decided to calculate the acidity on a basis of 1 kilogram (2.2 pounds) to bring the figures into conformity with Fuller's scale, now very generally employed by bacteriologists.

Carried out according to this method, the determination of the acidity of corn is easily made. Any physician ought to be able to carry it out accurately, for it is far easier than to determine the acidity of gastric juice, a determination with which every physician is familiar. Graduates in pharmacy will find no trouble in performing it and it is suggested that manufacturers of human food from maize and other persons who do not wish to bother with these determinations might have them done by the local pharmacist.

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[a] Op. cit., p. 32. The writers are indebted to the article by Schindler for many valuable data incorporated in this paper.

Inasmuch as pellagra is peculiarly likely to appear in insane asylums, hospitals, and penal institutions, and inasmuch as such institutions are often compelled by law to purchase their supplies from the lowest bidder, it may be well before proceeding further to formulate rules which will enable their superintendents to specify a high grade of corn. It is advised that those purchasing corn meal for food purposes should insist that it meet the following three requirements:

(1) It shall not contain more than 12 per cent of moisture.

(2) It shall be made from degerminated corn.

(3) It shall not have a greater acidity than 30, determined by the method already detailed.

The first requirement is advised because even the best corn will spoil if it contains much moisture unless it is stored in a very cold and dry place; the second is advised because the germ, or embryo, with its high protein and fat content, is the chief point of attack by micro-organisms; the third is advised because the acidity is the simplest index of deterioration through the action of micro-organisms. All three will be discussed in detail in the second part of this paper.

PART II.—METHODS OF EXAMINING CORN.

CONDITIONS TO BE CONSIDERED.

In the examination of corn for deterioration two conditions must be considered: (1) The detection in otherwise sound corn of factors which render it liable to spoil at some future time, and (2) the detection of actual deterioration.

The detection of the former condition is very simple and consists of a determination of the moisture content, since excessive moisture content is believed to be the chief factor in causing corn to spoil.[a] Schindler[b] believes that whole corn to be safe should not contain when stored more than from 13 to 15 per cent of moisture. It is probable that in this country 15 per cent is too high a limit.

Thoroughly air-dried corn contains about 12 per cent.[c] Corn with a much greater moisture content has either been harvested too soon, as is often necessary in cold, wet seasons, or it was shelled without adequate curing on the cob. Storage under conditions which do not protect it from the weather may, of course, increase the moisture content. Such corn is particularly liable, given a favorable opportunity, to heat and ferment.

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[a] Scofield, C. S., op. cit., p. 20.

Duvel, J. W. T. The Deterioration of Corn in Storage. Circular 43, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909.

Shanahan, J. D., Leighty, C. E., and Boerner, E. G. American Export Corn (Maize) in Europe. Circular 55, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910.

[b] Op. cit., p. 7.

[c] Shanahan, Leighty, and Boerner, op. cit., p. 22.

For both whole corn and meal the drying test is the only reliable method of determining moisture and should always be applied in doubtful cases. However, for meal a different limit is required than for whole corn, since, given an equal moisture content, meal spoils more readily than whole corn. Schindler believes that 13½ per cent is the limit for meal; and that under ordinary conditions corn with a moisture content of 15 per cent will yield meal with a moisture content of 13½ per cent.[a] For this country both limits are probably too high. The actual method of carrying out these moisture determinations is so well known that it need not be described here. For the details the reader is referred to the paper of Brown and Duvel.[b]

It must, however, be pointed out that moist corn which is otherwise sound ought not to be condemned. Curing prior to storage should be insisted upon. Corn will then be in very excellent condition, fit for any use. It is perhaps worth while to point out in this connection that if growers and handlers of corn could be induced to dry corn adequately, this would result in a great addition to the wealth of the country, irrespective of any possible danger to the public health from the consumption of spoiled corn. This saving would be in at least three directions: (1) Much less good corn would deteriorate in transit and storage; (2) millions of gallons of water in the form of undesirable moisture in corn are transported annually from the corn belt; the cost of transportation of this water might be saved; (3) the germ in the corn kernel is a living thing. As long as it is not very dry it respires and gives off carbonic acid and water. Like all living things it uses up food in the process of respiration. The food it consumes is the material stored in the endosperm. It is clear that the more food the embryo respires away the less will be left for man. Now, it has been proved that the drier corn is the less it respires, until, as it approaches absolute dryness, respiration becomes minimal.[c] It is evident, then, that moist corn must lose in food value in the course of time more than dry corn. It is impossible at present to say exactly what this loss amounts to, because data on the variation of respiration with moisture content do not exist. It is probably not great enough to affect seriously any single owner of corn, but it is quite probable that if it were possible to calculate it for the country as a whole it would amount to a very large sum indeed.

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[a] Op. cit., p. 24.

[b] Brown, Edgar, and Duvel, J. W. T. A Quick Method for the Determination of Moisture in Grain. Bulletin 41, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1907.

[c] White, Jean. The Ferments and Latent Life of Resting Seeds. Proceedings of the Royal Society, vol. B 81, p. 417.

The method of detecting actual deterioration of whole corn differs from that for corn meal. The methods for each will therefore be considered separately.

EXAMINATION OF WHOLE CORN BY INSPECTION.

Good corn must be sufficiently dry, as has been discussed above. It must be mature. It should not contain many cracked, rifted, or broken kernels. The hull protects the kernel from the attacks of bacteria and fungi. If the hull is burst or the kernel broken, the grain is likely to become moldy. The rifts may be due to imperfect artificial drying or to the careless shelling of inadequately cured corn. However, care must be taken not to confuse rifts of this type with the small ones, which are entirely internal, due to shrinking of the horny layer. The latter do not penetrate the hull, and therefore are unobjectionable, because they do not give access to micro-organisms. They are due to artificial drying at too high a temperature or more frequently to drying very moist corn too rapidly. When grain is observed to be covered with white powder, it has probably been damaged by insects, the granary weevil (*Calandra granaria* L.), the rice weevil (*Calandra oryza* L.), the wolf moth (*Tinea granella* L.), the Angoumois grain moth (*Sitotroga cerealella* Ol.), or other insects.[a] Injury by insects is of importance for the same reason that a burst hull is. By piercing the hulls insects open the way for fungi. Good corn should not contain many moldy or bad kernels. Schindler[b] believes that a content of more than 5 per cent of them should not be allowed. This limit is probably a good one when the grain is examined in the laboratory in the careful way advised in this paper. When, however, the grain is examined in the usual way by the grain inspector, only the more seriously damaged kernels would be apt to be noticed, so that under these circumstances this limit is probably too high. Under these conditions 2 to 2.5 per cent of moldy or cob-rotten kernels is a safer limit.[c]

The mold or bacterial growth may be either superficial, the fracture surfaces of broken kernels being attacked with particular frequency, or it may be in the interior when this has become accessible as the result of cracks, rifts, or injury by insects. It is then almost always the embryo which is the site of the growth of micro-organisms, presumably because it presents the most favorable soil. Sometimes this growth is evident only as a faint, bluish-gray spot, barely perceptible through the hull covering the groove in which the embryo lies. It is easily overlooked by the inexperienced, and it is therefore wise to trim off with a small sharp-pointed knife the hull covering the groove of suspicious-looking kernels, when the sound or decayed condition of the embryo may be recognized by anyone. If the decay is more advanced, the embryo may appear distinctly bluish-green, and when the hull is removed it will be seen that the embryo has been more or less completely replaced by a bluish-green powder, the spores of the fungi. Such grain is often known as blue or black eyed corn. In extreme cases the entire surface of the kernels may be covered with this bluish-gray or greenish mold powder. This discoloration seems to be caused by members of the genus of molds known as Penicillium. Other molds will produce other shades of color. One sample of corn examined in the course of the present investigation was covered with a bronze-colored powder. Dr. Erwin F. Smith, of the Bureau of Plant Industry, who examined it, identified it as spores of *Aspergillus fumigatus.* Doctor Duvel in a personal communication states that he has not infrequently encountered corn spoiled in this way. It is stated that sometimes the embryo is colored reddish by *Micrococcus prodigiosus.* In deciding whether any given kernel is moldy or not, one must be careful not to be misled by the color of the tip cap, which is often naturally of a darker color than the rest of the kernel.

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[a] For details the reader is referred to "Some Insects Injurious to Stored Grain," by F. H. Chittenden, Farmers' Bulletin 45, U. S. Dept. of Agriculture, 1897.

[b] Op. cit., p. 15.

[c] See Shanahan, Leighty, and Boerner, op. cit., p. 42.

Corn which has heated in bulk may show the result of bacterial action rather than that of molds. It is often more or less irregularly discolored, showing lighter and darker blotches and streaks, more especially in the region of the embryo and toward the tip. These spots are colonies of micro-organisms which are not merely confined to the surface, but also invade the interior of the kernel. In extreme cases the heat developed may be so great that the corn becomes brown or black and charred.

Good corn, finally, should have the fragrance characteristic of good meal. Spoiled corn has sometimes a musty or a sour odor, which may be intensified by warming it slightly in some way, such as holding it for a few moments in the closed hand or by blowing the breath upon it. Good corn should have the characteristic, slightly sweet taste of good meal. Spoiled corn may lack this characteristic taste and is often bitter.

These are the external criteria by which corn may be judged in regard to its fitness for human food. Their practical application in examining corn will now be considered. The first point is to obtain a fair sample. As already indicated, samples should be taken from various parts of the mass of corn; from the top, the bottom, and different levels between, and from the sides. The number of samples to be taken will depend upon the quantity of corn. Whether the odor be musty, or sour, or like the interior of a silo is noted as each sample is taken. The general appearance of each sample must be observed, for in dealing with large masses of grain different conditions may be met with in different regions of the mass. If this proves to be the case, the different samples are best examined separately. Ordinarily, however, the various samples are thoroughly mixed and the sample for examination taken from the mixture at several different points. The moisture content is determined accurately.

The pile is then spread out in a thin layer and the corn examined to see whether it is of characteristic bright, shiny appearance or whether the kernels are dull, blotched, discolored, with colored embryo indicative of heating and fermentation, or whether they are pale and shriveled, sometimes indicative of immaturity. The presence of many rifted, broken, or cracked kernels, or of much foreign matter, such as weed seeds or such débris as pieces of cob, is noted. While the latter are not in themselves necessarily harmful, they are hotbeds of molds which are liable under favorable conditions to infect the sound kernels.[a] A large number of kernels are next examined, one by one, for insect injury, and with a sharp-pointed knife the hull is removed from the embryo to show whether its condition is good. By this superficial examination an idea is obtained of the number of spoiled kernels present, which if excessive must be determined.

To do this, small numbers of kernels from different parts of the sample as it lies spread out thin on the white paper are taken until there are at least 500 kernels. These are spread out on white paper and each kernel examined individually, the good being put in one pile and the bad in another. When all have been examined each pile is weighed and the percentage of spoiled kernels computed. This should not exceed 5 per cent.[b]

BIOLOGICAL EXAMINATION.

The biological examination of corn was first proposed by Sclavo.[c] It is based on the fact that the chief point of attack for micro-organisms is the embryo, or germ. If the action of the micro-organisms is enough to kill the germ, the kernel loses its power to germinate. The best seed corn germinates as high as 97 per cent and over.[a] The method of determining germination is very simple. For details the reader is referred to the paper of Hartley.[a] It is only necessary to add that at least 100 kernels should be tested. No tests were made upon commercial grades of corn in the work here reported, and therefore a standard can not be fixed. The Italian Government[b] has fixed as a limit a germinating power of 80 per cent, while Ori [c] protests that this limit is too low. He advocates a limit of 90 per cent. This test, simple and excellent though it be, is not universally applicable. If perfectly sound but moist grain be dried at too high a temperature, the germinating power may be destroyed though the grain be of excellent quality. This is not likely to happen in the United States, for the driers do not ordinarily work at a sufficiently high temperature. Indeed, it is stated in a personal communication by Doctor Duvel, of the Office of Grain Standardization of the Bureau of Plant Industry, that he has known moist corn to gain in germinating power by being passed through a drier.[d] Furthermore, if corn of very high germinating power were mixed with spoiled corn of very low germinating power, this admixture might escape detection though it exceeded 5 per cent, because the germinating power might still exceed 90 per cent.

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[a] See Shanahan, Leighty, and Boerner, op. cit., p. 23.

[b] See p. 14.

[c] Sclavo, Vincenzo. Gazzetta Medica di Torino, vol. 52, October 24, 1901, p. 853.

It may be well, apropos of the dependence of the biological test upon the sound condition of the embryo, or germ, to point out the importance of the germ in determining the quality of the manufactured meal. As already indicated, the germ is the chief site of attack by micro-organisms. By removing the germ from corn that has not been too badly spoiled the greater part of the micro-organisms and their products will be removed. If the statements of European investigators concerning the toxicity of spoiled corn are to be believed, it follows that degerminated spoiled corn is less toxic than it was before the removal of the germ. Indeed, it has been shown that in the process of milling the more unwholesome material goes into the poorer grades of meal, which contain the starchy part of the endosperm lying next to the germ, and also into the germ,[e] which in this country is used for the manufacture of corn oil and stock feed. Moreover, the high oil content of the germ renders meal from whole corn less desirable than that from degerminated corn, since the oil is likely to become rancid. These are the reasons why in the foregoing part of this paper the advice was offered that meal from degerminated corn should have preference over that from whole corn. These considerations also render it likely that lye hominy is a wholesome form of corn, for the treatment with lye not only removes the hulls and germ but destroys micro-organisms. The method of determining whether meal has been made from whole or degerminated corn will be given later in discussing the chemical methods of examination.

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[a] See Hartley, C. P., "The Production of Good Seed Corn," Farmers' Bulletin 229, U. S. Dept. of Agriculture, 1905, p. 19.

[b] Rivista Pellagrologica Italiana, vol. 5, p. 122.

[c] Ori, A. La Diagnosi delle Alterazioni del Maiz in Chicchi ed in Farina. Rivista Critica de Clinica Medica, 1906, p. 165.

[d] See Webber, H. J., in appendix (p. 22) to paper of C. P. Hartley previously cited.

[e] Balp, S. Venticinque Anni di Lotto contra la Pellagra (1881–1906), Biella, 1908.

The methods hitherto presented, namely, the determination of acidity, moisture, and germinating power, and the examination by inspection, are adequate for the examination of whole corn. Only the first two are, however, applicable to meal. These are chemical methods, and chemical methods are relied on mainly in dealing with meal.

CHEMICAL METHODS.

SIGNIFICANCE OF THE ACIDITY DETERMINATION.

The most important and the most universally applicable chemical method is the determination of acidity. This has already been adequately treated, but the analytical data on which the writers base their procedure and their estimate of its value will be given.

The effect of fineness of grinding upon the determination has been investigated. It has been found that when corn is ground fine enough to pass through a sieve with 16 meshes to the inch, only a little is gained by making the grinding finer, as shown in Table I. The difference between a sample that had passed through a 16 mesh and the same sample passed through a 24 mesh was only half a cubic centimeter of the alkali. Twenty meshes to the inch has therefore been fixed upon by the writers as a convenient standard. Most commercial meals will pass through such a sieve.

TABLE I. *Relation of fineness of sample and length of extraction to the acidity determination.*

Determination.	Ground to 16 mesh; stood 24 hours.	Ground to 24 mesh; stood 24 hours.	Ground to 16 mesh; stood 5 hours; infrequent shaking.	Ground to 16 mesh; stood 5 hours; frequent shaking.
	c. c	*c. c.*	*c. c.*	*c. c.*
Acidity	36.5	37.0	32.5	34.5

An endeavor was also made to shorten the time of extraction. The acid from the meal passes very slowly into the alcohol. Even after twenty-four hours the extract has not attained the maximum acidity. The figures show, however, that extraction for twenty-four hours gives uniform and comparable results, and this is all that is necessary for practical purposes. Extraction for five and seven hours gives values too low (Table I). For reasons of practical convenience, therefore, twenty-four hours has been fixed upon by the writers as the standard time of extraction, even though it will not record the maximum acidity. As long as the determination can not be finished within the eight hours of the working day there is no object in making the extractions less than twenty-four hours. Warming the flasks hastens the extraction, but is objectionable because it causes much zein to go into solution. Moreover, at the higher temperatures a variation of a few degrees makes far more difference than in a determination at room temperature. This would introduce a source of error unless a thermostat were used; further, the use of heat with or without a thermostat would complicate the method. It is possible to shorten the time of extraction by vigorous shaking (Table I). In the regular determinations the flasks were merely turned upside down several times, three or four times the first eight hours, and once a little while before the titration. This shaking by hand occupied but a few moments. During the remainder of the time the flasks stood quietly at room temperature. By the use of a shaking machine the time of extraction could no doubt be shortened very much. Should this determination ever come into general use, large establishments testing many samples daily could use a shaking machine with profit. A machine was not used in the present investigation, because it would complicate the procedure and because each machine would have to be adjusted for a definite set of conditions.

The effect upon the acidity determination of slight changes in the concentration of the alcohol has also been examined. These have to be considered because of the variation in moisture content of corn samples. This moisture would dilute the alcohol and might introduce an error. Acidity determinations were therefore made with 80 per cent as well as with 85 per cent alcohol. The moisture would never be likely to be sufficient to lower the strength of the alcohol from 85 per cent to 80 per cent. Determinations were made upon a sample of spoiled meal that was very acid and upon a sample of good meal. The results are presented in Table II. The differences due to the variations in concentration of the alcohol obtained are insignificant.

TABLE II.—*Relation of alcohol concentration to the acidity determination.*

No. of sample.	80 per cent alcohol.	85 per cent alcohol.
12	76 c. c. N. alkali.	78 c. c. N. alkali.
16	22 c. c. N. alkali.	22 c. c. N. alkali.

Table III is a presentation of the acidity of a number of samples of seed corn of various strains from various parts of the country. Mr. C. P. Hartley, Physiologist in Charge of Corn Investigations, Bureau of Plant Industry, furnished most of the samples. The determinations were made in February, 1910, except No. 10, which was made in December, 1909. The samples contain specimens of the crop of 1909 and 1908. It is seen that the acidity ranges from 13 to 24 c. c. and that the 1908 corn is no more acid than that of 1909. No. 51 is from the same ears as No. 50; it differs from the latter in consisting only of the smaller kernels from the tips of the ears. No. 28 is corn specially bred for low-protein content, while No. 29 was specially bred for high-protein content. No. 40 is corn prematurely ripe, such as is often produced in years with exceptionally warm and dry autumns.

TABLE III.—*Acidity and moisture of selected samples of high-grade corn from various sections of the United States.*

No. of sample.	Name of variety.	Ash.	Acidity.	Moisture.	Locality.
		Per cent.	*c. c.*	*Per cent.*	
1	Sturgis Hybrid, 1908	1.59	18.0	7.60	Connecticut.
2	White North Dakota Flint, 1908	1.22	18.0	8.11	North Dakota.
3	Barnwell White, 1908	1.25	17.5	7.93	South Carolina.
4	Marlboro Prolific, 1908	1.25	13.0	7.71	Do.
5	Boone County White, 1908	1.29	15.0	7.47	Tennessee.
6	Huffman, 1908	1.42	13.0	8.25	Do.
7	Strawberry, 1909	1.55	18.0	7.56	Texas.
8	Marlboro Prolific, 1909	1.38	15.0	10.09	South Carolina.
9	Boone County White, 1909	1.23	13.0	7.81	Tennessee.
10	Whole corn, selected ears, 1909	1.18	23.0	10.00	Maryland.
28	Low-protein corn	....	16.5	....	Illinois.
29	High-protein corn	....	19.5	....	Do.
40	Prematurely ripe white corn	....	24.0	....	District of Columbia.
50	Whole seed corn	....	16.2	....	Virginia.
51	Corn tips	....	16.5	....	Do.

Small samples of meal were purchased in the open market in Washington, D. C., Summerville, S. C., Boston, New York, and Chicago, In all the cities but Washington the samples were purchased from little stores in the parts of town where poor people trade. In Washington the samples were purchased in different parts of the city, in the fashionable residential section as well as the poor quarters. The results are presented in Table IV. This table also includes meal No. 11, ground in the laboratory from corn which had been allowed to spoil in the bin of a grain elevator at Baltimore during the course of an experiment conducted by Doctor Duvel,[a] who very kindly furnished not only this sample but also many others. Doctor Duvel and Mr. Shanahan, the Crop Technologist in Charge of Grain Standardization, Bureau of Plant Industry, gave much help and advice. Nos. 12 and 14 were from two institutions in which cases of pellagra had occurred. It will be seen that a considerable number of samples have too high an acidity.

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[a] See Duvel, J. W. T., "The Deterioration of Corn in Storage," Circular 43, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909.

TABLE IV.—*Acidity of samples of commercial corn meal purchased in several cities in the United States.*

No. of sample.	Variety.	Water.	Ash.	Acidity.	Locality.
		Per cent.	*Per cent.*	*c. c.*	
11	Whole corn, spoiled	9.5	1.50	37	Baltimore.
12	White meal	10.0	1.04	78	Illinois.
14	.....do	10.7	2.00	60	Arkansas.
15	.....do	10.0	1.47	33	Washington, D. C.
16	Yellow meal	10.8	.33	23	Do.
17	White meal	10.4	1.03	39	Do.
18	Yellow meal	10.0±	.22	17	Do.
19	White meal	10.0±	1.08	29	Do.
20	.....do	10.0±	1.06	29	Do.
21	.....do	10.0±	1.30	41	Do.
22	.....do	10.0±	1.05	....	Do.
23	.....do	10.0±	1.26	37	Do.
24	.....do	10.0±	.98	24	Do.
30	.....do	....	....	23	Summerville, S. C.
31	.....do	....	....	28	Do.
32	.....do	....	....	16	Do.
33	.....do	....	....	30	Do.
34	Yellow meal	....	....	37	Boston.
35	.....do	....	....	37	Do.
36	.....do	....	....	35	Do.
37	.....do	....	....	19	Chicago.
38	.....do	....	....	20	Do.
39	.....do	....	....	23	Do.
41	.....do	....	....	19	New York.
42	.....do	....	....	23	Do.
43	.....do	....	....	40	Do.
44	.....do	....	....	21	Do.
45	.....do	....	....	18	Do.
46	.....do	....	....	16	Do.
47	.....do	....	....	13	Do.
48	.....do	....	....	29	Do.
49	.....do	....	....	17	Do.

The mother substances of the acid formed have not yet been finally determined, but some of the analytical results give indications as to their nature.

TABLE V.—*Analyses of different portions of a carload of damaged corn.*

Sample.	Water.	Ash in dry material.	Acidity.	Fat in dry material.	Nitrogen in dry material.
	Per cent.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*
No. 25, top	11.53	1.51	95.0	4.25	2.53
No. 26, 2 inches from top	8.33	1.41	73.0	3.94	1.86
No. 27, 6 inches from top	8.06	1.24	64.0	3.87	1.29
Normal corn	[a] 10.75	[a] 1.50	[b] (15–30)	[a] 4.2	[a] 1.60

[a] Wiley.

[b] Schindler.

Table V gives analyses of three samples of corn taken from the same car while undergoing heating. No. 25 was taken at the surface, No. 26 was taken 2 inches below, and No. 27 was taken 6 inches below the surface. Appended to Table V is an analysis of average corn published by Wiley.[a] No. 25 had sprouted but had been killed before growth had advanced beyond a beginning. It was covered with blue-green mold and had a very musty odor. To the eye, nose, and tongue it was one of the worst specimens handled. No. 26 was less moldy but still had a musty odor blended with a sour smell. No. 27 was characteristic of heated corn and had a very sour smell.

These differences may be due to the fact that on the surface corn the aerobic fungi flourished, while down in the interior the anaerobic ones developed. It must, however, be remembered that scientists are at variance as to the mechanism which causes the heating of vegetable material when it is bulked. There are three views. Some believe that the heating is due in the main to bacterial action.[b] Others believe that it is due to the action of oxidizing enzymes.[c] Finally, Boekhout and Ott de Vries[d] have shown that oxidation can take place by simple catalysis under conditions which exclude the intervention of micro-organisms as well as enzymes. No similar studies have been made upon corn or, indeed, upon any other seed, so that as yet it can only be surmised what takes place in these cases. It will be seen that No. 25 with the highest acidity has also the highest fat and nitrogen content. This is not due to an absolute increase in these substances but to a relative one caused by the disappearance of some other substance which can not be anything other than carbohydrate. Here is evidence, then, that carbohydrate, in this single case at any rate, furnished the material from which acid was formed. This is in accord with what is known in general about fermentation and with the observations of Italian authors.[e]

It is, of course, probable that the fat is more or less saponified, thereby becoming rancid, and that the fatty acids formed contribute to the acidity. This point is being investigated by the writers. It is particularly important in the light of recent researches upon the toxicity of unsaturated fatty acids.[f]

The figures of Table V are perhaps not typical of all cases of spoiling. It is even probable that under different conditions quite a different state of affairs may be found. These figures are to be regarded only as a single instance until more samples of a similar nature are analyzed.

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[a] Wiley, H. W. Composition of Maize. Bulletin 50, Bureau of Chemistry, U. S. Dept. of Agriculture.

[b] Miehe, H. Die Selbsterhitzung des Heus. Jena, 1907.

[c] Loew, O. Curing and Fermentation of Cigar-Leaf Tobacco. Report 59, U. S. Dept. of Agriculture, 1899.

[d] Boekhout, F. W. J., and Ott de Vries, J. J. Über Tabaksfermentation. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, vol. 24, pt. 2, p. 496.

[e] Gosio, B. Ricerche Batteriologiche e Chimiche sulle Alterazioni del Mais. Contributo all' Etiologia della Pellagra. (Memoria 2 a) Rivista d'Igiene e Sanità Pubblica, vol. 7, 1896, p. 825.

[f] Faust, E. S. Über chronische Ölsäurevergiftung. Archiv für Experimentelle Pathologie und Pharmakologie. Supplement, 1908, p. 171.

The writers have begun investigating the nature of the substances which render the extracts acid. This seemed important because zein might be one of them. Zein is one of the chief proteins of the endosperm. It probably does not occur at all in the embryo before germination.[a] It is soluble in moderately strong alcohol, insoluble in dilute and absolute alcohol, and behaves somewhat like an acid in combining with a certain amount of alkali. Its solubility in alcohol insures its being present in the extracts. As it is more soluble in hot than in cold alcohol it seems possible that differences in the temperature of the room during extraction might cause more or less of it to pass into solution and thus affect the results. It was therefore important to determine whether the increased acidity of spoiled corn was dependent to any considerable degree upon the zein. To settle this point both the acidity and the nitrogen content of the extract of both spoiled and sound corn was determined. The nitrogen content would give an index of the amount of zein that had gone into solution. The figures obtained are given in Table VI. Under the heading "Kjeldahl nitrogen" is given the amount of nitrogen, as determined by the Kjeldahl method in the amount of alcoholic extract used for the titration (25 c.c.). The same extract used in the titrations was used for the nitrogen determinations. Hence the acidity and the nitrogen figures are quite comparable.

TABLE VI.—*Relation between the total nitrogen and the alcoholic extract of corn meal.*

No. of sample.	Kjeldahl nitrogen.	Acidity.
	Grams.	*c. c.*
14	0.0139	60.0
10	.0297	23.0
25	.0099	95.0
26	.0140	73.0
27	.0105	64.0
28	.0081	16.5
29	.040	19.5

It will be seen that the very acid extract from the spoiled corn contains less nitrogen and therefore less zein than the extract from good corn except sample No. 28. Now No. 28 is a low-protein corn. Its acidity is low and the small amount of nitrogen in the extract seems to depend not on the acidity but upon the low-protein content of the grain. This assumption gains in probability by the figures obtained with No. 29, which is a high-protein corn. This gives the highest nitrogen figure and yet differs in acidity by only 3 c. c. from No. 28, which gives the lowest nitrogen figure. This difference in the behavior of low and high nitrogen corn is very suggestive from a number of points of view. From the present standpoint it is of interest that although the amount of nitrogen in the alcoholic extract probably influences to a slight degree the acidity values obtained under the present conditions it can not possibly influence them enough to invalidate the usefulness of the acidity determination. Furthermore, in sound corn the acidity of the extract can depend only partly upon zein, and in spoiled corn it can depend only to a slight degree upon it.[a] As a matter of fact it would seem that less nitrogen is extracted when the acidity is high. The question arose whether the lessening of the nitrogen extracted is due to a consumption of zein by the micro-organisms causing the deterioration or whether acidity renders zein less soluble.

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[a] Soave, M. L'Azoto della Zeina in Relazione all' Azoto Totale e all' Azoto delle Altre Sostanze Proteiche nel Mais. Le Stazioni Sperimentali Agrarie Italiane, vol. 40, p. 193.

To test this, good corn was extracted with neutral alcohol in the usual way and also with alcohol to which sulphuric acid had been added until its acidity corresponded to that of spoiled corn. The result did not come up to expectations, for the differences were insignificant as the following figures show:

Extraction with neutral alcohol and with acidified alcohol.

Sample 16.	Extracted by 85 per cent alcohol.	Extracted by 85 per cent alcohol+5 c. c. H_2SO_4 N/10.
	Grams.	*Grams.*
Kjeldahl nitrogen	0.0241	0.0221

These negative results, together with the figures obtained for low-protein (No. 28) and high-protein (No. 29) corn, make it probable that it is not the acidity developed but the destruction of alcohol-soluble nitrogenous material which accounts for the low-nitrogen content of the alcoholic extracts of very acid corn.

The conversion of the corn protein into other substances was a matter which gave considerable food for thought. As long as it was not known that zein was an unimportant factor in causing the acidity of the extracts it was deemed possible by the writers that altered zein might be the cause of the acidity. As already pointed out, zein behaves in some respects like an acid. The putrefaction of proteins is accompanied among other processes by their deamidization, i. e., the removal of ammonia, either as such or in the form of amins. The removal of these basic groups might increase the acid properties of the proteins. It was possible that zein might in this way become more acid without sacrificing its solubility in alcohol. However, when it was found that the acidity did not depend to any large degree upon zein the investigation of this point was postponed to some future time. For the present the fact is noted that the zein from spoiled corn was found to be different from that prepared from sound corn. When freshly precipitated it is not so tough, but rather brittle and of a dirty green color, even when obtained from white corn. It could not be decolorized with any of the ordinary fat solvents; a study of the nature of the change is now being made.

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[a] Prof. L. H. Smith, of the Illinois Agricultural Experiment Station, kindly furnished samples of low-protein and high-protein corn.

These considerations suggest the possibility of corn spoiling so as to become alkaline from the formation of ammonia and amins. This would of course ultimately take place, but probably not until all the starch in the grain had been used up. When it did occur decomposition would be so far advanced that use of the corn as food would be quite out of the question. The possibility of ammoniacal decomposition does not therefore vitiate the acidity test.

The nature of the acids formed has also been studied by the writers. This seems to be an intricate question, since it involves more than a simple acetic or lactic acid fermentation. A number of interesting results have been obtained which it is hoped to communicate at a future time. For the present the fact is recorded that a peculiar volatile crystalline acid has been encountered which could not be identified as any of the ordinary fermentation acids. It is possible that it is identical with the acid isolated by Gosio,[a] and it is hoped that its identity may be learned.

ASH DETERMINATION.

The ash determination is done in the usual manner. However, corn is quite difficult to ash without employing temperatures so great that there is danger of loss by volatilization. Experience has taught that the following manipulations are useful. Porcelain is best used, as platinum is badly attacked. The heating is begun with a very small flame, and at least half an hour is allowed for the material to become charred. In this way a porous mass is obtained. Rapid heating causes the meal to char and covers it with a coating of fused salts which effectively keeps the oxygen from gaining access to the carbon. In the course of an hour or two the flame is gradually raised to the full heat of an ordinary Bunsen burner. When after a time the carbon does not seem to be disappearing, the crucible is cooled and water added. This water is then evaporated off on the steam bath. The pieces of carbon float on the surface and climb up the sides of the crucible, so that when the crucible is dry and is again heated they burn off readily. Sometimes a second treatment with water is necessary.

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[a] Op. cit., p. 871 et seq.

In Italy the amount of ash present is regarded as significant. An ash content of over 4 per cent is considered a sure sign of deterioration.[a] Undoubtedly it is. Fermentation increases the ash content because the fungi causing the fermentation consume organic matter in the corn kernel, converting it into carbonic acid and water, which are dissipated into the atmosphere. None of the salts disappear. Consequently, since the organic matter in the fermented kernel is lessened, the relative proportion of salts and similar constituents is increased and the percentage of ash rises correspondingly. An inspection of Table III shows that the ash content of good corn can be considered as being in the neighborhood of 1.5 per cent. Inspection of Tables IV and V shows further that badly spoiled corn (Nos. 11, 25, 26, and 27) does not necessarily have a very high ash content. Only in meal No. 14 is it noticeably high. Evidently conditions are different in Italy or else corn far more badly spoiled than any seen in the course of this investigation is common. There was no sample with more than 2 per cent of ash, yet Tables IV and V show that in a general way ash content and acidity run parallel. The ash determination is troublesome, the acidity determination easy. Therefore in most cases the former may be omitted.

From another point of view the ash determination is significant. It gives an indication as to how completely a meal has been degerminated and the starchy layer of the endosperm removed. Nearly all the ash of the kernel is located in the germ. Hence, the poorer the meal in ash the more complete the removal of the germ and the adjacent starchy layer. How desirable it is to degerminate corn has already been shown. This is again expressed in the ash and acidity determinations of Table V. Thus, the meals most completely degerminated, those with the lowest ash content, show also the lowest acidity. Nos. 16 and 18 were yellow meals milled for the northern market and consisted almost exclusively of the horny layer of the endosperm. The very fact that American meals vary so much in the degree of degermination renders ash determinations an unsatisfactory method for the examination of meal. Thus, meal made from thoroughly degerminated corn would have a low ash content. Subsequently, owing to moisture or faulty storing, it might become very bad indeed without showing an ash content as high as that of meal from whole corn.

FAT DETERMINATION.

Although the ash determination gives an index of the degree of degermination of a meal, this can be estimated more accurately by a fat determination. The germ contains only 10 per cent of ash, but it has often over 30 per cent of oil. Consequently, the fat determination is the more delicate index of the two. Whole corn contains on the average about 4.3 per cent of fat. High-grade, rather coarse meal, consisting only of the horny layer, may contain as little as 0.8 per cent of fat. Meals on the average will vary between these limits according to the degree of degermination. In one other direction the fat determination is useful. It makes it possible sometimes to determine whether a meal has been adulterated with the germ. No such case has been met with in the present research, but it seems to have been attempted in Europe. Millers have there adulterated their low-grade meals with the germ obtained as a by-product in the manufacture of their high-grade meals. Such adulterated meal will of course show a fat content high above that of whole corn.

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[a] Antonini, G., op. cit., p. 74.

The fat determinations are carried out in the usual way with a Soxhlet extractor.

THE PHENOL REACTION OR TEST OF GOSIO.

In Italy much stress is laid upon the phenol reaction. Schindler [a] discards it as uncertain; it could be obtained only once, in sample No. 25, the worst one dealt with. This fact strengthens the suspicion that corn as bad as that which seems to be common in Italy is rare in this country.

The phenol test depends upon the formation by molds of substances giving color reactions with ferric chlorid. The Penicillium molds, or at least some of them, are said to produce this substance or substances. Gosio [b] has endeavored to isolate the substance. He obtained a small amount of a crystalline substance giving a color with ferric chlorid, possibly parahydrocumaric acid. It was not toxic. Gosio,[b] Gosio and Ferrati,[c] and Antonini and Ferrati [d] all believe that the toxic substance and the substance giving the color with ferric chlorid are identical. They believe that the toxicity and the reaction of Gosio run parallel. These views are not accepted by all Italians and have been particularly vigorously attacked by Ceni.[e] Most Italian investigators believe this reaction to be caused by phenols or phenol acids. This belief is based not upon the isolation and chemical identification of these substances, but upon the ferric-chlorid reaction and the fact that extracts giving this reaction kill mice with symptoms resembling carbolic-acid poisoning. When it is considered how many substances give color reactions with ferric chlorid and, further, how difficult it is to form any opinion of the identity of a poison from the symptoms it produces in animals, it must be concluded that it is premature to pass judgment on the chemical nature of these substances.

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[a] In a personal communication.

[b] Op. cit., p. 869 et seq.

[c] Gosio, B., and Ferrati, E. Sull' Azione Fisiologica dei Veleni del Mais Invaso da Alcuni Ifomiceti. Rivista d'Igiene e Sanità Pubblica, vol. 7, 1896, p. 961.

[d] Antonini, G., and Ferrati, E. Sulla Tossicità del Mais Invaso da "Penicillium glaucum." Archivio di Psichiatria, Scienze Penali ed Antropologia Criminale, vol. 24, p. 581.

[e] Ceni, C. Sulla Reazione Fenolica in Rapporto coi Tossici Pellagrogeni. Rivista Pellagrologica Italiana, vol. 6, 1906, p. 60.

In its original form the reaction of Gosio is performed in either of the following ways:

(*a*) From 50 to 100 grams of meal are warmed for several hours in twice their volume of 80 per cent alcohol. The alcohol is then filtered off into a porcelain dish and evaporated to dryness. The residue is then taken up with warm water, filtered, and the filtrate treated with a dilute solution of ferric chlorid. A coloration varying from dark green to bluish violet results.

(*b*) The meal is suspended in water acidified with a few drops of phosphoric acid. The acid suspension is exhausted with ether, the ethereal extract evaporated to dryness, and the residue tested as above.[a] Antonini[b] advises that if the first-mentioned procedure is followed the extraction be continued for several days, shaking from time to time and exposing to the sunlight. In order to avoid resins and fats which may obscure the reaction, the residue may be extracted with boiling water, the extract filtered, and the filtrate tested. If the second procedure is followed, he advises using three times as much 1 per cent phosphoric-acid solution as corn (by volume) for the extraction, and he prolongs it for several days, shaking thoroughly, exposing to sunlight, and warming slightly. The writers attained the best success with this modification. When the extraction has gone on long enough, the suspension is cooled, and then treated with two to three volumes of ether. This is allowed to separate and the clear ether, which alone should be used, is decanted. It is shaken out repeatedly with distilled water to remove impurities. Finally, the clear ether is decanted from the water, distilled off, and the residue tested.

According to Antonini, Camurri has modified the test of Gosio by distilling the meal with water or steam and performing the reaction upon the distillate. The reaction is said to be even more distinct if it be performed upon the ethereal extract of the distillate.

THE REACTION OF ORI.[c]

The reaction of Ori depends upon the fact that molds contain or produce a substance or series of substances which decompose peroxid of hydrogen catalytically. The substance producing this decomposition is believed to be an enzyme and has been called catalase. It is probably of universal occurrence in living things and therefore also occurs in the corn kernel. However, it seems to be more abundant in molds than in corn. Consequently, moldy corn or moldy meal will decompose peroxid of hydrogen more powerfully than good corn or good meal. The reaction is carried out as follows:

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[a] Gosio, B., op. cit., p. 883.

[b] Op. cit., pp. 74–75.

[c] Ori, A., op. cit.

Five grams of meal are extracted for half an hour with 15 c. c. of a 50 per cent aqueous solution of glycerin. The extract is then filtered through paper; 1 c. c. is put in a watch glass and 4 to 5 drops of a 3-per cent peroxid of hydrogen solution added. Good degerminated meal gives no bubbles at first, while bad meal produces a strong effervescence almost at once.

The writers conclude that in general this reaction gives a good indication of the condition of the meal if the meal be thoroughly degerminated. As Ori himself points out, the reaction is more reliable than that of Gosio, while, as his figures show, it runs parallel with the acidity. Judged by his figures, it does not seem to be more delicate. Now, good corn kernels, as already stated, contain a certain amount of catalase, and therefore meal made from whole corn decomposes peroxid of hydrogen to a certain extent. Usually, however, this is not as extensive as when the corn is moldy. The writers found by taking corn kernels, splitting them, paring the germ carefully away, and making extracts separately of the endosperm and the germ that the catalase is located almost exclusively in the germ.[a] The extract of the germ gives practically as powerful a reaction as spoiled meal. Here, then, are possibilities of confusion. Thoroughly degerminated meal ought not to decompose peroxid of hydrogen. Meal from good whole corn will decompose peroxid of hydrogen to a certain extent. Hence, it is conceivable that meal from very thoroughly degerminated corn may become somewhat moldy and yet give Ori's reaction no more intensely than meal from good whole corn. Therefore, in order to form a correct estimate of the value of the reaction in any given case it ought to be known whether the product was obtained from degerminated material. Viewed from this aspect the reaction of Ori has its value. On the other hand, there is another possibility. It seems conceivable that meal might be made from corn spoiled in such a way that the molds were situated mainly in the germ. If in the process of milling the corn were thoroughly degerminated and carefully bolted, the greater part of the molds might be removed.

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[a] Since making these experiments it was discovered that similar observations upon wheat have been made very recently by P. Liechti. See Die Prüfung von Mehlen auf Grund ihres Gehaltes an Katalase, Vorläufige Mitteilung, Chemiker Zeitung, vol. 33, p. 1057.

In such a case the corn might show a fairly high acidity and nevertheless a weak reaction of Ori. Meal with high acidity and negative action upon peroxid of hydrogen was actually encountered by Ori, and he points out that this phenomenon might in some way be connected with degermination.[a] There is still another factor to be taken into consideration. Catalase is an enzyme. It is therefore weakened or destroyed by temperatures of 60° C. and higher. Artificially dried corn might, therefore, when carelessly dried, lose its power to decompose peroxid of hydrogen.

It is quite possible that with these limitations this reaction might be developed into a useful rapid method if it were made quantitative. This ought to be easy, either by measuring the volume of oxygen evolved in a unit of time or by titrating the excess of peroxid of hydrogen remaining after a given time.

Ori has also suggested another test based upon the fact that corn does not contain appreciable amounts of invertase, while most molds do. It is applied by putting 30 grams of meal into a flask with 90 cubic centimeters of 50 per cent aqueous solution of glycerin. After standing for twenty-four hours the extract is filtered off and twice its volume of 90 per cent alcohol added to it. The precipitate formed by the alcohol is collected upon a filter and dissolved in 45 c. c. of distilled water. Of this solution 2 c. c. are added to 50 c. c. of a 10 per cent cane-sugar solution and the mixture incubated for twenty-four hours at 50° C. It is then tested for reduction and the sugar titrated. Good meal should produce no reduction or only a minimal one. This test has not been used in this investigation.

THE DETERMINATION OF TOXICITY.

Much stress is laid in Italy upon the determination of toxicity. Schindler does not even mention it. It is performed as follows: A weighed quantity of meal is extracted at about body temperature with 90 per cent alcohol for twenty-four hours. It is then filtered and the alcoholic filtrate evaporated until the alcohol is removed. The residue is taken up in water at a temperature of 40° C., made up with warm water to a definite volume so that 0.5 c. c. corresponds to about 0.5 grams of the meal, and an amount equivalent to 0.5 grams of meal injected subcutaneously into a mouse. Larger quantities of liquid are often injected, but this seems open to objection in so small an animal. The mouse is chosen because it is supposed to be the most sensitive to the poison.[b] The symptoms are described as consisting of clonic spasms and localized contractures of the muscles, embarrassed respiration, gradual paralysis, collapse, death. Sometimes opisthotonos ensues. On autopsy little is said to be noticeable except inflammation at the site of injection and hyperæmia of the cord.

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[a] Ori, A., op. cit., p. 187.

[b] Gosio, B., and Ferrati, E., op. cit., p. 964.

A sample of corn which was toxic when injected in the dosage given above was never encountered in the present investigation. However, the procedure was varied from that of the Italians because of the following considerations: The extracts may be very acid. It is well known that herbivorous animals are very sensitive to acids which they are incapable of destroying in their metabolism. The symptoms of such an acid intoxication (acidosis) are, however, different from those described above. The behavior of mice toward acid intoxication is not known so far as a hasty search of the literature has shown. It is therefore conceivable that some of the toxic effects of the injection of corn extracts may merely have been acid effects. For these reasons the solutions injected were usually neutralized. Perhaps that is why toxic effects were not obtained. In this connection it is interesting to note that Gosio and Ferrati[a] distinctly state that alkali neutralizes the poison, and in another place that culture fluid of Penicillium cultures becomes less toxic as the culture grows older and its acidity diminishes.

TESTS FOR MICRO-ORGANISMS AND FOR A TENDENCY TO BECOME MOLDY.

The test for micro-organisms and the tendency to become moldy involves the quantitative determination of the number of organisms in the suspicious sample compared with a sound sample. The methods hitherto proposed for this purpose do not seem to be adequate. To devise improved ones and to determine the nature of the organisms present is beyond the limits of the present problem. This has been undertaken by Dr. Erwin F. Smith, of the Bureau of Plant Industry, and he will no doubt report in due time.

A number of other tests have been proposed by various authors, such as the application of Millon's test and the bromin water test, to corn extracts. They are based on the assumption that the toxic substances of spoiled corn are phenols. Neither seems to offer any special advantage.

These, then, are the chief methods hitherto used for determining the fitness of corn for food. Although the writers lay the most stress upon the determination of acidity, each of the other tests has its uses. Under ordinary circumstances the examination will probably have to be limited to the acidity determination, while the expert food chemist and bacteriologist will control his results by using a number of other methods and thus reach an estimate more nearly correct than any single method can give.

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[a] Op. cit., p. 978.

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B. T. GALLOWAY, *Chief of Bureau.*

BREEDING NEW TYPES OF EGYPTIAN COTTON.

BY

THOMAS H. KEARNEY,
Physiologist in Charge of Alkali and Drought Resistant
Plant Breeding Investigations.

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B. P. I.—611.

BREEDING NEW TYPES OF EGYPTIAN COTTON.[a]

INTRODUCTION.

The work of the Bureau of Plant Industry with Egyptian cotton in the Southwestern States and Territories involves three closely related but somewhat distinct lines of investigation, as follows:

(1) Plant-breeding investigations, the object of which is to secure improved, high-yielding varieties and strains by the selection of superior individuals producing fiber which represents the best commercial types of Egyptian cotton. The present publication deals mainly with this phase of the work.

(2) Acclimatization investigations, the object of which is to study the diversity exhibited by imported and by more or less acclimatized stocks when planted under different environmental conditions, so as to ascertain what environments and what cultural conditions are most favorable to uniformity, fruitfulness, and the production of good lint in each stock.[b]

(3) The study of irrigation and other cultural methods for growing the crop and of industrial methods for preparing and marketing the product. These studies are directed by the officers of the Bureau of Plant Industry who are in charge of the cooperative

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[a] The general results of the experiments with Egyptian cotton in the southwestern United States up to the end of the year 1908 were described in Bulletin 128 of the Bureau of Plant Industry, entitled "Egyptian Cotton in the Southwestern United States," and in Circular 29 of the same Bureau, entitled "Experiments with Egyptian Cotton in 1908," both publications being by Thomas H. Kearney and William A. Peterson.

[b] Some of the results of the investigations in this field by Mr. O. F. Cook and his assistants are described in the following publications of the Bureau of Plant Industry: Bulletin 147, entitled "Suppressed and Intensified Characters in Cotton Hybrids," by O. F. Cook, 1909; Bulletin 156, "A Study of Diversity in Egyptian Cotton," by O. F. Cook, Argyle McLachlan, and Rowland M. Meade, 1909; Circular 42, "Origin of the Hindi Cotton," by O. F. Cook, 1909; Circular 53, "Mutative Reversions in Cotton," by O. F. Cook, 1910.

work with the Reclamation Service and with the Office of Indian Affairs, respectively. Mr. W. A. Peterson, superintendent of the cooperative experiment farm of the reclamation project at Yuma, Ariz., and Mr. E. W. Hudson, superintendent of the cooperative experiment farm on the Pima Indian Reservation at Sacaton, Ariz., are in immediate charge of the cultural experiments. Most of the experimental work with Egyptian cotton in the Southwest has thus far been carried on at these two stations.

In 1909 the plant-breeding plats were located in the Yuma Valley[a] and at Sacaton, Ariz. In the Yuma Valley two fields were planted with bulk seed of the two most promising of the new types described later, four fields were each planted with imported seed of one of the Egyptian varieties, and various smaller experimental plantings were made. At Sacaton, in addition to the plant-breeding plat and the plats grown from imported seed of Egyptian varieties, a field of 10 acres was grown from mixed seed of the "bulk selections" made at Sacaton in 1908. In the Imperial Valley, California, small field plantings of four different types of the acclimatized stock were made, each in a different locality. Another of the acclimatized types was tested at Glendale, near Los Angeles, Cal., alongside a planting of newly imported seed of the Mit Afifi variety.

The results of the season's work were on the whole very encouraging. For the first time in the course of these experiments, fields of several acres each were planted to high-bred varieties and strains, each derived from a single individual plant selected in the breeding nursery only two years previously. A gratifying degree of uniformity in the plants and fiber was exhibited. The best three of these new types are described in detail in the present publication. Two of them, the "Yuma" and the "Somerton" varieties, are so distinct from the Mit Afifi variety, with which the breeding work was begun, as to warrant the assumption that they constitute mutations. The third (strain No. 361) is a typical Mit Afifi, but superior in yield, earliness, and quality of the fiber to plants grown from imported seed of that variety. This strain is apparently a product of acclimatization and selection without the aid of mutation.

The great amount of diversity that manifested itself in the experimental fields in 1908 was largely eliminated, partly as a result of planting these selected stocks and partly through the application of methods of "roguing" at an early stage in the development of the plants which Mr. Cook has worked out as a result of his studies of diversity. Samples of the fiber produced at Somerton and Sacaton in 1909 were submitted to a number of buyers and spinners, who have given uniformly favorable reports on its quality. Comparisons with cotton of the corresponding grades imported from Egypt have invariably been favorable to the Arizona product.

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[a] The experimental plantings in the Yuma Valley in 1909 were located near the village of Somerton, about 14 miles south of the town of Yuma. In 1910 most of the experimental work near Yuma is located on the new cooperative experiment farm situated on the California side of the Colorado River, about 7 miles above the town of Yuma.

NEW TYPES DEVELOPED.

The varieties and strains[a] of Egyptian cotton described in this paper were derived from a stock of seed of the Mit Afifi variety imported from Egypt by the Office of Seed and Plant Introduction and Distribution and tested at several localities in the Southwest in 1902.[b] They are all descended from individual-plant selections made in the field at Carlsbad, N. Mex., that was planted with this seed. In 1906 the surviving progenies of these selections were transferred to Yuma, Ariz., and since then the breeding work has been continued in that locality. In 1909 a plant-breeding nursery was started at Sacaton, Ariz., with seed of a number of individual selections from the progeny rows at Yuma of the previous year, in addition to seed of a number of individual selections made in 1908 in the 10-acre field at Sacaton.[c]

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[a] In this bulletin the term "variety" is applied to such of the new forms as can easily be distinguished from the original stock by their botanical characters. The two new varieties described are believed to have originated as mutations. Where the differences are simply of degree—greater fruitfulness, earlier ripening, longer and stronger fiber, etc.—and no evidence of mutation is shown, the term "strain" is employed.

[b] For an account of the earlier experiments, see Bulletin 128, Bureau of Plant Industry, United States Department of Agriculture, 1908, pp. 34–45.

[c] The field planting of 1908 at Sacaton was made with mixed seed from the 1907 breeding rows at Yuma. As would be expected, considerable diversity was noted among the plants in this field. A large number of individuals which were superior to the average in fertility and in fiber qualities and which appeared to be purely Egyptian in all their characters were marked and picked separately. The mixed seed from these plants was used for planting the "general field" at Sacaton in 1909, in order to ascertain the general fertility and state of acclimatization of the stock after the removal of all hybrids and other conspicuously inferior individuals and to afford a further opportunity for the selection of desirable types of plants that might appear under the Sacaton conditions. The result was a marked improvement in average fruitfulness and in the quality of the fiber as compared with the 1908 field. The same method of "bulk selection" was repeated in 1909. It will be interesting to compare the performance of this second generation of bulk selections with that of carefully selected varieties and strains derived from single individuals, which will also be tested on a field scale at Sacaton in 1910.

METHODS OF SELECTION.

The breeding methods employed have been very simple. At the outset all the plants in the test field were examined, and those individuals which were most fruitful, ripened earliest, and had the largest bolls and the best fiber were given numbered tags and were picked separately. The seed cotton from these plants was then carefully compared in the laboratory and the final selection of the most promising individuals was made.

The following year the seed from each of these selections was planted in a progeny row, and each row was marked with the number of the corresponding selection. When the bolls began to open in the fall the rows were carefully worked over, and the best individuals were selected. This process has been continued year after year.

As the work developed, the methods were improved. Latterly more importance has been attached to the "projected efficiency" of the individual selections as shown by the greater or lesser degree of uniformity in the good qualities of their progeny. It is now the practice to begin the work of selection each year by a general survey and comparison of the progeny rows as units. As a result, many of the rows can be rejected at once, either because the plants show too much diversity or because their average fruitfulness, length of lint, and other qualities are inferior. Further consideration is given to only those rows which show a high degree of uniformity and in which at least a majority of the individuals are desirable in all essential qualities.[a] The best individuals in the superior rows are then selected by careful comparison in the field, the branching habit and productiveness of the plants and the size of the bolls being noted and the lint from a number of bolls on different parts of the plant being combed out and examined in respect to length, strength, and general quality.

Evidence has accumulated to the effect that the type of branching of the plant is one of the most important characters to be considered in making selections. Plants which bear a large proportion of the bolls on the fertile branches of the main stem, with a corresponding reduction in the size of the "limbs,"[b] are to be preferred because they are much easier to pick and because the ripe bolls are held up better and escape contact with dust and mud. The ability to develop fruiting branches at low nodes of the axis—in other words, to set a "bottom crop"—is a desirable character, being an important factor in great fruitfulness. The size of the bolls must be considered, not only because large bolls make picking easier, but because this character is intimately associated with length of fiber.[a] It was discovered last year that an examination of the breeding rows several weeks before the bolls begin to ripen is exceedingly helpful, since it is much easier at that period to compare the different rows in respect to type of plant and amount of diversity. The percentage of contamination that has resulted from previous crossing with other types is especially easy to determine at this early stage.

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[a] An exception should be made to this rule in the case of strikingly superior individuals which are so distinct as to warrant the belief that they are mutations. Such individuals should be retained even if the rows in which they occur are otherwise inferior, in view of the generally admitted tendency of mutations to be prepotent.

[b] The distinction between the fertile branches and the "limbs," or large vegetative branches (which in Egyptian cotton are produced only at a few of the lowest nodes of the main stem), is well expressed by Mr. O. F. Cook in Bulletin 156 of the Bureau of Plant Industry, p. 29: "The branches of the cotton plant are of two definitely different forms. Fertile branches are horizontal or drooping.

The seed cotton from the preliminary selections made in the field is picked separately, and the fiber is carefully examined and compared on the seed in the laboratory. The seed cotton from each plant is then ginned, and the color of the resulting fiber is determined by matching with imported samples of the different Egyptian varieties.[b] The average amount of fuzz on the seeds is also recorded after ginning. By a careful comparison of the field notes on productiveness, earliness, vegetative characters of the plants, and size of the bolls with the results of the examination of the fiber in the laboratory, the final choice is made of the selections to be retained for planting in progeny rows the following year, and the rest are discarded. The more promising types are tested on a field scale by planting in differ-

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Each joint bears a fruit bud, and the internodes are twisted to bring the buds to the upper side. Sterile branches, or 'limbs,' are upright or ascending, with long straight joints and no fruit buds. The sterile limbs are to be thought of as subdivisions of the main stalk and have the same function. Like the main stalk they can produce other branches which are fertile, but are themselves unable to set any flowers or fruits."

[a] Mr. O. F. Cook has called attention in Bulletin 159 of the Bureau of Plant Industry, p. 45, to the existence of this correlation between the length of the boll and the length of the fiber. The writer has observed that in Egyptian cotton, although extremely long, narrow bolls sometimes contain inferior fiber, very short, rounded bolls are never correlated with long lint.

[b] Mit Afifi has the most deeply colored fiber. A comparison of the imported sample of this variety, which has been used as a standard, with the hand-painted specimens of color tints given in Ridgway's "Nomenclature of Colors" (Boston, 1886) shows the color of this sample to be very nearly intermediate between "cream-buff" and "pinkish-buff"; Nubari is somewhat lighter colored, corresponding very nearly with the "cream color" of Ridgway; Jannovitch fiber is much lighter colored than Nubari and may be described as of a very pale tint of cream color; Abbasi fiber is white, tinged with cream. To conform with commercial usage, however, the terms "brown" (Mit Afifi), "light brown" (Nubari), "cream colored" (Jannovitch), and "white" (Abbasi) will be used in this paper.

ent localities the mixed seed from the unselected plants in the progeny rows. The degree to which the type maintains its uniformity and desirable qualities of plant and fiber when grown in large fields, especially if at different localities affording a considerable diversity of climatic and soil conditions, is, of course, the final measure of its agricultural value.

The types represented by progeny rows in the breeding nurseries at Yuma and Sacaton in 1909 were designated by the following numbers: 300, 301, 310, 320, 330, 340, 350, 360, 361, 362, 363, 370, 380, 382, 383, and 390. Each of these numbers is that of an individual selection made at Yuma in 1907 and of the corresponding progeny row grown at Yuma in 1908. All types the numbers of which belong to the same decade (as 300 and 301, 360 to 363, etc.) are closely related, having been derived from the same individual plant selected at Yuma in 1906. All types numbered from 300 to 340, inclusive, came from one individual selected in the field at Carlsbad, N. Mex., in 1902, and all those numbered from 350 to 390, inclusive, are derived from several individual selections made in the breeding nursery at the same place in 1905.[a]

The progenies of numerous individual selections in each of the above types were grown on the "plant-to-a-row" system in the breeding nurseries at Yuma and at Sacaton in 1909. Strain No. 361 and the Yuma variety (No. 382) were tested on a field scale near Yuma, seed from the unselected plants in the respective progeny rows of 1908 having been used for these plantings. Selections from the progeny rows of the following seven types have been planted in the breeding nurseries of the present year (1910) at Yuma and Sacaton: Nos. 301, 310, 360, 362, 370 (the Somerton variety), 382 (the Yuma variety), and 390.

Heretofore the various progeny rows of all the types represented have been grown side by side in the breeding nurseries, with no attempt to isolate one from another. Even under these conditions most of the rows in 1909 showed a definite unity of type. This indicates a strong tendency to prepotency in the characters of several of these types, for in Arizona the Egyptian cotton generally crosses very freely even with other species when grown near by, and a high percentage of hybrids results.[b] Hereafter, in order to prevent, if possible, any contamination due to intercrossing of the different stocks, the progeny rows of each of the most promising types will be isolated, as far as practicable, from all cotton of different ancestry.

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[a] Owing to an accident to the stakes at the heads of most of the rows in the breeding nursery of 1905, the detailed records of the earlier ancestry of strains 350 to 390 were lost, but they are all descended from the same stock of imported Mit Afifi Egyptian seed that was grown at Carlsbad in 1902.

[b] Owing to the fact that plats of Upland varieties were grown in the neighborhood of the breeding rows of Egyptian cotton at Yuma in 1907, many of the progeny rows in 1908 contained a high percentage of hybrids. In one row there were as many as 25 per cent of first-generation Egyptian-Upland hybrids.

The three most promising types that have so far been developed in the course of this breeding work are described in detail in the following pages. The remaining types either appear less promising or have not yet been sufficiently tested.

THE YUMA VARIETY.

Type No. 382, here designated the "Yuma" variety, is upon the whole the most promising that has so far been developed in this breeding work, and is the one which has been most thoroughly tested on a field scale. In 1909 a field of 4¼ acres near Yuma, Ariz., was planted to this seed, and a high degree of uniformity was noted in the characters of the plants, which were very productive and had large bolls with lint of good quality. Seed of the Yuma variety was planted in 1910 at all localities where experiments with Egyptian types of cotton were undertaken, in order to test its power of retaining its desirable qualities under a variety of conditions of climate and soil.

HISTORY OF THE VARIETY PREVIOUS TO 1909.

The progenitor of the "Yuma" variety was a plant selected in the breeding nursery at Carlsbad, N. Mex., in 1905. It was derived from the stock of Mit Afifi Egyptian seed planted at Carlsbad in 1902, from which all the other types described in this paper are likewise descended. In the progeny row grown at Yuma, Ariz., in 1906 from the Carlsbad selection an individual was selected which was characterized by high productiveness, very large bolls, nearly smooth seeds, a high percentage of lint (32 per cent), and fiber that was very satisfactory in length, strength, and fineness. The progeny plants of this selection in 1907 were of excellent average quality. One of the selections, No. 382, from this progeny row was the immediate progenitor of this variety. It was a very productive plant, with large, long-pointed bolls, and its fiber was silky and lustrous, very strong, and more than 1½ inches in length.[a] The lint percentage (27) was considerably lower than that of its progenitor in 1906.

The amount of crossing which takes place under these conditions in Arizona seems far in excess of what has been observed by most cotton breeders in the eastern United States. It can doubtless be attributed to the unusual abundance of wild bees and other flower-visiting insects in the cotton fields during the summer and early fall.

[a] Measurements of length of fiber are copied from the score cards of the year the sample was grown. It is probable that the length was somewhat too favorably estimated previous to 1908, the earlier practice having been to give the

The progeny row in 1908 from selection No. 382 was remarkably uniform in the characters of the plants, bolls, and fiber.[a] The plants were characterized by great productiveness and by a habit of growth (Pl. I, fig. 2) that distinguished this row from all the other progeny rows in the nursery. They had a tall, stout main stem, which generally greatly surpassed the limbs and bore an exceptionally large proportion of the bolls. The bracts of the involucre were very large and the bolls were long and pointed. The seeds were generally nearly smooth. The average length of fiber equaled or exceeded that of any other of the 1908 progeny rows, and the length throughout the row was fairly uniform. The seed cotton from all the unselected plants in this row was picked and ginned together. As measured by Mr. John A. Walker,[b] the resulting lint ranged from $1\frac{1}{4}$ to $1\frac{3}{8}$ inches in the first picking, $1\frac{3}{8}$ to $1\frac{7}{16}$ inches in the second, and $1\frac{7}{16}$ to $1\frac{1}{2}$ inches in the third picking. In respect to fineness, Mr. Walker classed the lint from the first two pickings as "fine" and that from the third picking as "strictly fine and silky." He found the strength to be "fair" in the first picking and "extra" in the second and third, but in all three pickings the strength was slightly uneven. The color of the lint from all the pickings was light brown.

Twenty individual selections were made in this row, and the seed cotton from each was carefully compared. Although the fiber was generally of high quality, there was much diversity among the different plants and even on the same plant, especially as between the first and the third pickings. In 13 of these plants the fiber had the same color as imported samples of the Jannovitch variety (see footnote *b*, p. 11), in 4 plants the color was intermediate between Jannovitch and Nubari, in 1 plant the fiber was nearly as brown as Nubari, and in another nearly as white as Abbasi. The maximum length of fiber in the 20 selections ranged from $1\frac{5}{16}$ to $1\frac{11}{16}$ inches, in 16 plants the length did not fall short of $1\frac{3}{8}$ inches, in 7 plants none of the fiber was shorter than $1\frac{7}{16}$ inches, and in 2 plants the minimum

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fibers a decided pull in straightening them out before measuring them. During the last two years the fibers have been merely smoothed out, without applying tension. It is therefore probable that the deterioration of the progeny of many of the selections which is indicated by length of the fiber shown on the score cards is apparent rather than real. It is believed that the method now followed gives a better idea of the length as usually estimated commercially on samples of ginned cotton; error, if any occurs, is in the direction of too great conservatism.

[a] This row contained only 4 per cent of first-generation Egyptian-Upland hybrids, as compared with 6 to 25 per cent in eleven other rows in the breeding nursery. The small percentage of hybrids in row 382 indicates a high degree of prepotency in this type.

[b] An expert grader of Egyptian cotton, employed by the Bureau of Plant Industry to classify the lint from the different experimental plantings in Arizona in 1908.

length was 1½ inches. The variation in length on the same plant was generally considerable, especially as between the first and the third pickings. The fiber was uniformly silky and very fine, especially in the later pickings. In nearly all plants the strength was satisfactory, and in 7 out of the 20 it was highly so. The percentage of lint varied considerably, having been only fairly good on 8 out of the 20 plants, while on the other 12 it was more satisfactory. In 10 out of the 20 selections the seeds varied from nearly smooth to partly covered with fuzz, in 5 they were nearly smooth, and in the other 5 they varied from nearly smooth to completely fuzzy. The third picking almost always showed a higher percentage of nearly smooth seeds than did the first.

BREEDING EXPERIMENTS IN 1909.

The seed from 14 of these selections was planted in 1909 in progeny rows, 8 at Yuma and 6 at Sacaton. When inspected by Mr. Argyle McLachlan on July 6, there was considerable diversity in 3 of the 8 rows at Yuma, although the foliage type (large, thick, dull-colored, generally three-lobed leaves) was fairly uniform in all. In one row no evident hybrids were found, while in the other rows 2 to 6 per cent of the plants were hybrids and were rogued out. In September the tendency to develop a stout main stem greatly overtopping the limbs was found to be much less pronounced than in progeny row No. 382 of 1908. The plants were generally productive and early ripening, with long spreading or drooping fruiting branches well furnished with bolls. The bracts were large, the bolls large and taper pointed, and the seeds generally partly covered with fuzz.[a] The color of the fiber was generally about that of imported Jannovitch, but was frequently a deeper shade of brown. An unfavorable character was the readiness with which the ripe seed cotton dropped from the open bolls, a peculiarity which necessitates frequent picking. In 4 of the 8 rows at Yuma no selections were made, the fiber having been uniformly short. In fact, none of the rows averaged nearly as good in length of fiber as did the progeny row of 1908 in which their progenitors were selected.

In the 6 rows at Sacaton the plants were very similar in habit, foliage, shape of bolls, productiveness, early ripening, and fiber characters to those at Yuma. One row contained no recognizable hybrids, but from each of the other rows 1 to 5 hybrids or otherwise aberrant individuals were rogued out on August 3. Two of these rows were later discarded, the fiber being uniformly too short to warrant making selections.

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[a] There is a general tendency to an increased development of fuzz on the seeds in Egyptian cotton grown for several generations in the Southwest.

Individual selections of the Yuma variety were made in 1909 in 4 of the progeny rows at Yuma and in 4 of the rows at Sacaton, the total number of selections being 16 at Yuma and 23 at Sacaton. In addition to these, 32 individual selections were made in the large field planted to this variety at Yuma, which is described in the following paragraphs. The seed of these selected plants is being grown in progeny rows at Yuma and Sacaton in 1910.

FIELD TEST IN 1909.

Seed from the unselected plants in progeny row No. 382, grown at Yuma in 1908, was picked together and was used in 1909 for planting a field of 4¼ acres in the Yuma Valley. The soil was a rather light loam, and although probably as uniform as could be found in any area of equal size in that locality, there was sufficient difference in soil texture in different parts of the field to cause certain spots to dry out more rapidly after irrigation. The plants in these spots were smaller, the leaves smaller and lighter colored, the flowers opened earlier, and the bolls were generally smaller and opened earlier than elsewhere in the field. The lint was also generally shorter, coarser, and weaker on the plants growing in these spots.

From June 17 to June 22 this field was carefully inspected by Mr. Argyle McLachlan, who rogued out about 2 per cent of the total number of plants as being hybrids or otherwise conspicuously aberrant. On July 24 the field was again carefully examined by Mr. McLachlan and the writer; the plants then appeared remarkably uniform in branching habit, foliage, and other characters. Upon closer examination about one-half of 1 per cent of the plants were found to give indications of hybrid origin or were otherwise aberrant, and these were removed. As the result of these two roguings, therefore, not more than 2½ per cent of the entire stand of plants were found to be appreciably different from the type of the variety. This indicates a very satisfactory degree of uniformity and also a high degree of prepotency, since the progeny row of 1908, which furnished the seed for planting this field, was situated among rows of very different types, in some of which there was a high percentage of hybrids with Upland varieties. (See footnote *b*, p. 12.) Such diversity as was exhibited later in the season by the plants that remained after the second roguing seemed to be well within the limits of individual fluctuation in a "pure" type.

The total yield from this field of 4¼ acres was 7,390 pounds of seed cotton, or 1,740 pounds per acre. On the basis of an average lint percentage of 27.5[a] this is equivalent to a yield of slightly above 475 pounds of fiber per acre.

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[a] A 25-pound sample of seed cotton from the first picking yielded 29 per cent of lint, an equal weight from the second picking 30.4 per cent, and an 85-pound [illegible]

The relatively low percentage of lint given by the acclimatized Egyptian cotton as compared with the percentages reported in Egypt and those obtained during the earlier years of the acclimatization work in the Southwest is largely explained by an observation made by Mr. McLachlan, who finds that the delinted seeds are considerably larger and heavier in the acclimatized types as now developed. Mr. McLachlan found that imported Mit Afifi seed cotton gave a lint percentage of 33 to 35 and that the delinted seeds weighed only 10 grams per 100. The acclimatized Yuma variety, which gave only 27.5 per cent of lint, had seeds weighing 13 grams per 100. If the seeds had weighed no more than imported Mit Afifi seeds the lint percentage of the Yuma variety would have been 33 (a satisfactory percentage for Egyptian cotton) instead of 27.5. Evidently, therefore, no actual diminution in the quantity of lint on the individual seeds has taken place during the process of acclimatization.

CHARACTERS OF THE PLANTS AND FIBER.

The distinctive features of most of the plants in this field were the same as those of the select progeny rows of the Yuma variety as previously described. The plants (Pl. I, fig. 2) were large and showed a strong tendency to develop a stout main stem surpassing the limbs in height and to produce and retain their fruiting branches well toward the base of the main stem and larger limbs.[a] The fruiting branches were long and spreading or drooping and bore numerous bolls. The

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sample from the third picking 27.2 per cent, giving an average for the three pickings of 29 per cent. But since another sample of 50 pounds of seed cotton made up of equal weights from each of the three pickings yielded only 26 per cent of lint, it is deemed fair to take 27.5 per cent, the average of these two results (29 and 26), as the closest possible approximation to the average lint percentage for the entire product from this field, very little of the total having been ginned at this writing.

[a] Mr. Argyle McLachlan early in the summer made a special study of the plants in the 4-acre field with respect to fruiting branches. He found that the first fruiting branch was developed at the ninth to fourteenth node from the base of the stem as compared with the thirteenth to seventeenth node in a planting of imported seed of the Mit Afifi variety. On thirty representative plants from different parts of the field the average lowest node at which a fruiting branch developed was the tenth. It has been pointed out by Mr. Cook that ability to develop fruiting branches at low nodes of the stem, and hence to set a "bottom crop," must considerably increase the earliness and yield of a cotton plant.

The type of plant characteristic of the Yuma variety is described in Mr. McLachlan's report as follows: "The plants are 6 to 8 feet tall with a leading main stem, 5 or 6 vegetative branches nearly as long as the axis but loaded with fruit and consequently spreading at an angle of 50 to 60 degrees, and above them on the axis pendent fruiting branches—a plant of symmetrical, broad-spreading, inverted-kite shape."

leaves were large, comparatively dull green, and usually three lobed. Even when five lobed the leaves were considerably longer than broad, owing to the great length of the middle lobe. The bracts of the involucre were exceptionally large and more or less connate at the base, and the bolls were long and taper pointed (Pl. III). The bolls opened early and completely and there was a somewhat marked tendency to drop the ripe seed cotton. The seeds were generally large for an Egyptian type of cotton and bore a greater amount of fuzz than is usually the case with seed of Mit Afifi cotton as grown in Egypt. The fiber was of fair length (ranging from $1\frac{1}{4}$ to $1\frac{7}{16}$ inches, averaging probably $1\frac{3}{8}$), of satisfactory strength and fineness, and of a pale-brown color, intermediate between that of the Nubari and that of the Jannovitch varieties, as represented by samples imported from Egypt. (See footnote *b*, p. 11.)

The strength and fineness of the lint were tested by Mr. L. H. Dewey, in charge of Fiber Investigations, the tests having been made on three samples of the bulk cotton from unselected plants in the general field. Two of the samples were from the second picking only, while the third sample was made up of equal parts from the first, second, and third pickings. Fiber ginned from the mixed seed cotton of the unselected plants in one of the progeny rows of this variety at Sacaton was also tested. The results of the tests were as follows:

TABLE I.—*Strength and diameter of fiber of the Yuma variety of acclimatized Egyptian cotton grown at Yuma and at Sacaton, Ariz., in 1909.*

Sample.	Breaking strength.		Diameter.	
	Average.	Variation.	Average.	Variation.
Field at Yuma:	*Grams.*	*Grams.*	*Microns.*	*Microns.*
Second picking only	6	4 - 9.5	24	18.5-30
	7	4 -11	24.5	19 -30
First three pickings, equally mixed	5.5	4 - 8.5	27	22.5-33.5
Progeny row at Sacaton	7.3	4.5-11	25.3	22.5-33.5

PERFORMANCE OF NEARLY RELATED TYPES.

Tests made in 1909 of two other types (Nos. 380 and 384) closely related to the Yuma variety (No. 382) are of interest as showing the general excellence of this group. Both of these types are derived from the same individual selection of 1906 which was the progenitor of the Yuma variety. The progenitor of each was an individual selection made in the same progeny row of 1907 in which plant 382 was selected. The progenies of the two selections of 1907 were grown in rows in the breeding nursery at Yuma in 1908, and the bulk seed from the unselected plants in each of these rows was used for the plantings in 1909. One of these types (No. 384) was planted near the town of El Centro, in the Imperial Valley, California. The plants were very uniform in branching habit and foliage and showed only Egyptian characters, but one aberrant individual having been found among the fifty or more plants in this plat. The fiber was long, silky, and very strong—the best fiber of the Egyptian type produced in the Imperial Valley in 1909. The other type (No. 380) was planted in a test row at Yuma. The plants throughout the row were productive and had long, pointed bolls and large bracts similar to those of the Yuma variety. The seeds were generally smooth; the fiber averaged $1\frac{3}{8}$ inches in length and was silky, very strong, and light colored.

PROBABLE MUTATIVE ORIGIN OF THE YUMA VARIETY.

The "Yuma" variety, type No. 382, was derived from imported seed of the Mit Afifi Egyptian variety. Most of the strains which have descended from the same original lot of seed are still typically Mit Afifi in all their characters, as was evident from comparison with plants grown from newly imported seed of that variety in 1908 and 1909. Nevertheless, this particular type now shows little resemblance to the parent variety. In the color of the lint it resembles more nearly the Jannovitch variety. It is especially remarkable for the long, taper-pointed bolls (Pl. III), which are much like those of the Abbasi variety and are in marked contrast to the short, blunt bolls of typical Mit Afifi (Pl. II). The manner of growth of the plants, the characters of the foliage, and the large involucre bracts are also diagnostic. The vegetative characters and the peculiarities of the seed and fiber have recurred with conspicuous regularity wherever seed of this variety or of nearly related types has been planted. The distinctiveness of the characters and their remarkable uniformity indicate that the variety originated as a mutation.[a] The history of such Egyptian varieties as Abbasi and Jannovitch, which are reported in Egypt to have developed from the widely grown and older Mit Afifi variety, makes it altogether probable that they originated as mutations from that variety in the same manner as the Yuma variety in this country.

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[a] The peculiar branching habit and foliage of the plants were not especially noticed until 1908, when progeny row No. 382 was observed to stand out very distinctively from all other rows in the breeding nursery. Yet the large size of the bolls was noted as early as 1906 in the individual selection of that year, from which this variety is descended. This, together with the close resemblance in the characters of the related type No. 380 (descended from the same individual selection of 1906 which was the progenitor of the Yuma variety), indicates that the mutation occurred at least as long ago as 1906. The incompleteness of the records for the earlier years of this breeding work makes it impossible to determine whether the actual mutation occurred earlier than 1906. It is possible, although not probable, that it was present as an admixture in the Mit Afifi seed imported from Egypt with which the work was begun in 1902.

THE SOMERTON VARIETY.

Type No. 370, here designated the "Somerton" variety, is remarkable for the sharply defined characters of the plants and bolls, and is like the Yuma variety in the great uniformity manifested in these respects. It has not yet been adequately tested on a field scale, but the progeny rows grown at Yuma and at Sacaton in 1909 showed it to be a very distinct and definite type. It is being tested in field plantings in 1910 in comparison with the Yuma variety.

HISTORY OF THE VARIETY PREVIOUS TO 1909.

The ancestry of the Somerton variety was similar to that of the preceding down to the year 1905, when the individual plant selection from which the Somerton variety is derived was made in the breeding nursery at Carlsbad, N. Mex. This plant was fairly productive and very early ripening and had small bolls and smooth seeds well covered with lint (percentage, 33). The fiber was fairly uniform in length, with an average of fully 1½ inches; it was brown in color, strong, and very fine. In the 1906 progeny row at Yuma planted with seed grown from this plant, the selected individual which was the progenitor of the Somerton variety was a small, fairly well-shaped, very productive, and early-ripening plant which had medium-sized bolls and smooth seeds well furnished with lint (percentage, 30.5). The fiber was 1½ inches long, very uniform, light brown in color, strong, and very fine. The 1907 progeny row from this plant was characterized by exceptionally early ripening. One of the individual selections made in this row, No. 370, was the immediate progenitor of the variety. It was an extremely productive plant, but the percentage of lint was only 26.5. The bolls were large[a] and the fiber was more than 1½ inches in length, uniform, fine, fairly strong, and cream colored.

Progeny row No. 370 contained in 1908 only 1.5 per cent of hybrids, a remarkably small proportion as compared with most of the other rows in the breeding nursery that year. (See footnote *b*, page 12.) The plants in this row were large and very productive, with a well-developed main stem surpassing the longest of the limbs. The latter were spreading or ascending. The bolls were large and remarkably sharp pointed. The seed cotton from the unselected plants in this row was picked and ginned together. The resulting lint was light brown in color; that from the first two pickings was classed by Mr. John A. Walker as "fine and strong" and that from the third as "strictly fine, silky, and extra strong." In length of fiber the first picking averaged $1\frac{3}{8}$ inches, the second ranged from $1\frac{3}{8}$ to $1\frac{7}{16}$ inches, and the third picking ranged from $1\frac{7}{16}$ to $1\frac{1}{2}$ inches. The excellent luster of the fiber in this row was noted in the field.

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[a] It will be noted that while the 1905 selection had small bolls and the 1906 plant only medium-sized bolls, the 1907 progenitor of this variety had large bolls. While the bolls were increasing in size from year to year, the percentage of lint was diminishing from 33 per cent in 1905 to 30.5 per cent in 1906 and 26.5 in 1907. (In regard to the decreased lint percentage, see p. 17.)

The seed cotton from the ten individual selections of 1908 was carefully compared. In seven of these the fiber was a little lighter colored than imported Nubari cotton, in two the fiber was slightly darker than imported Jannovitch, and in one the fiber was the same color as Jannovitch. The extreme range of length among these ten selections was from $1\frac{1}{4}$ to $1\frac{5}{8}$ inches, but the fiber was generally at least $1\frac{7}{16}$ inches long. The average strength was inferior to that of the selections from most of the other progeny rows of 1908. The general appearance of the fiber was very similar in the ten selections and indicated a distinct and uniform type. There was a strong tendency to smooth seeds.

EXPERIMENTS IN 1909.

Eight of the selections from progeny row No. 370 of 1908 were grown in progeny rows in 1909, six at Yuma and two at Sacaton. The rows at Yuma when inspected by Mr. McLachlan on July 6 showed a higher degree of uniformity and a more distinctive type of plant than any other group of progeny rows in the breeding nursery. Only two of the rows showed any trace of contamination; one contained a single probable hybrid and another had two suspicious-looking plants. The plants were bushy, large in diameter, with five to eight limbs nearly as long as the main stem, the internodes of which were unusually short. The leaves were exceptionally large and were usually broader than long. They were five lobed, with deep clefts between the lobes.[a] On July 23, when first inspected by the writer, the plants in all the rows had an exceptionally vigorous appearance and were distinguished by the unusually bright green color of the foliage. The two progeny rows at Sacaton, inspected August 3, showed the same type of plant and the same high degree of uniformity as the rows at Yuma. There were no obvious hybrids and only one suspicious-looking individual in each row.

On September 23 the plants in the six rows at Yuma had grown very large and were ripening late. The fruiting branches were set well toward the base of the plant and were well furnished with bolls.

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[a] A somewhat similar habit and type of foliage characterized the plants grown at Yuma in 1909 from imported seed of the Nubari variety.

The seeds were generally smooth and rather poorly furnished with lint.[a] Individual selections were finally made in only two of the rows, the fiber in the other rows being too scanty and also inferior in length. Numerous selections were made in the two rows at Sacaton, in both of which the plants were characterized by high average fertility. The total number of individual selections of the Somerton variety made in 1909 was twelve at Yuma and eighteen at Sacaton.

The seed cotton from all of the unselected plants in one of the progeny rows at Sacaton was picked and ginned together. The lint was light brown, corresponding in color with imported fiber of the Nubari variety. The strength and diameter of the fiber were tested by Mr. L. H. Dewey, who reported the average breaking strength as 6.3 grams (variation 3.6 to 11.5 grams) and the average diameter as 23 microns (variation 18.7 to 30 microns). This diameter indicates a finer fiber than is shown by the fiber tests of the Yuma variety as reported in Table I (p. 18).

Seed from the unselected plants in progeny row No. 370 of 1908 was planted in 1909 at Yuma, Ariz., and at Brawley, in the Imperial Valley, California. In the small planting at Yuma the plants were of good average fertility, with generally large bolls and smooth seeds. The fiber was satisfactory in length, reaching 1⅜ inches on many plants and falling below 1¼ inches on hardly any. It was of good strength and medium fineness. In the 1-acre field planted with this seed at Brawley the plants were very uniform in appearance, and, with the exception of four hybrid individuals, showed only pure Egyptian characters. The fruiting branches, which were well furnished with bolls, were developed at low nodes on the stem. The bolls were large.

CHARACTERS OF THE PLANTS AND FIBER.

The Somerton variety as exemplified in the progeny rows at Yuma and Sacaton in 1909 is characterized by a great spread of branches, numerous long limbs, and long fruiting branches which are developed well toward the base of the plant and bear numerous bolls. The plants at about the time they begin to blossom have a symmetrical, rounded, bushy appearance and are exceedingly leafy. The large leaves are of a brighter green color and of softer texture than in the Yuma variety. They are usually five lobed and broader than long, while in the Yuma variety they are generally three lobed and considerably longer than broad. The bolls (Pl. IV), which resemble those of the Abbasi Egyptian variety, are long and taper to an extremely sharp point, sharper than in the Yuma variety. The seeds have a strong tendency to be smooth and are frequently devoid of even the tuft of green or brown fuzz at each end which characterizes the seeds of the Mit Afifi variety in Egypt, while in the Yuma variety the sides of the seeds are usually partly covered with fuzz. The lint is very fine, but its percentage is less than in the Yuma variety. In color it is usually darker, varying from that of the Jannovitch to that of the Nubari variety. It shows about the same range of length as that of the Yuma variety.

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[a] The average percentage of lint obtained by ginning the seed cotton from the thirty individual selections of the Somerton variety made at Yuma and Sacaton was 25.1 per cent, as compared with 26.7 per cent for the thirty-nine individual selections of the Yuma variety and 29.9 per cent for the eight selections of strains Nos. 360 and 362.

PERFORMANCE OF A NEARLY RELATED TYPE.

Seed from another individual selection from the same progeny row of 1907 in which plant No. 370 was selected was grown at Yuma in 1908. Seed from all the unselected plants in the 1908 row was picked together and was used for planting a small plat in the neighborhood of Los Angeles, Cal., in 1909, alongside a similar planting of imported seed of the Mit Afifi variety.[a] The plants made only a small growth, produced comparatively few bolls, and ripened very late. On September 13, when none of the bolls had yet opened, no difference could be detected between the plants from the acclimatized and those from the imported seed, but in the quality of the fiber produced, the acclimatized ultimately proved very superior. The fiber was fine and silky and excelled in strength any other cotton of the Egyptian type grown in the Southwest in 1909. The average breaking strength, as reported by Mr. L. H. Dewey, was 8 grams (variation from 4 to 12 grams), and the average diameter 25 microns. As compared with this the fiber produced by the plants from the newly imported Mit Afifi seed in the same field was decidedly weaker and coarser, its average breaking strength being 6.8 grams (variation from 4 to 14.8 grams) and its average diameter being 30.6 microns.

PROBABLE MUTATIVE ORIGIN OF THE SOMERTON VARIETY.

Like the Yuma variety the Somerton variety is very distinct from the Mit Afifi stock with which this breeding work was begun and shows a high degree of prepotency, as evidenced by the remarkable uniformity which it has maintained notwithstanding abundant opportunities for crossing with other types. These facts give good ground for the belief that it has originated as a mutation. It is possible that the mutation occurred in 1907, since the breeding records show that the 1905 ancestor of the strain had small bolls and the 1906 ancestor medium-sized bolls. The 1907 progenitor, which was the first recorded as having large bolls, may well have been the original mutant, but unfortunately no detailed description was made of the vegetative characters of this plant. The plants of a nearly related type grown near Los Angeles (p. 23) were so unlike those in any planting of Egyptian types of cotton that has been made in the Colorado River region,[a] that it was impossible to decide whether this stock shares the vegetative characters of the Somerton variety. If it had been grown under similar conditions and had exhibited the same characteristics, ample evidence would have been afforded that the mutation must have occurred at least as early as 1906.

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[a] This planting near Los Angeles, under the direction of Mr. O. F. Cook, was made to ascertain the effect of very different climatic conditions upon the habit of the plants and upon the expression of diversity in a stock that had been acclimatized in the Colorado River region as compared with newly imported seed. It was realized, of course, that the conditions in that part of California are not favorable to cotton culture on a commercial scale.

STRAINS NOS. 360, 361, AND 362.

ORIGIN OF THE GROUP.

The group of strains Nos. 360, 361, and 362, like the Yuma and Somerton varieties, was derived from an individual selection made at Carlsbad, N. Mex., in 1905, in a part of the breeding nursery where the numbers of the progeny rows had been lost. The ancestry of the group previous to 1905 is therefore unrecorded except that each strain was derived from the same lot of imported Mit Afifi seed used in beginning the breeding work in 1902, from which all the varieties and strains described in this paper originated. An individual selection in the progeny row from the Carlsbad plant grown at Yuma in 1906 is the common ancestor of this group of strains. The plants representing the progeny of the individual selected in 1906, grown in a row at Yuma in 1907, were noted as being uniformly excellent. Three individual selections of that year, numbered as above, are the direct progenitors of the three corresponding strains.

STRAIN NO. 360.

Selection No. 360 of 1907 was characterized by a satisfactory percentage of lint (30 per cent) and by fiber that was fully 1½ inches long, uniform in length, fine, and of a good brown color, but rather inferior in strength. The 1908 progeny row from this plant contained about 11 per cent of hybrids. The remaining plants were uniform and were typically Mit Afifi in their characters. They were productive, ripened early, and produced fiber that was distinctly brown in color. The seed cotton from the unselected plants in this row was picked and ginned together. The lint had an average length of 1⅜ inches in the first picking and ranged from 1⅜ to 1½ inches in the second picking. The strength and color were very satisfactory in both pickings. Three individual selections were made in this row, and the seed was planted in progeny rows in 1909, two at Yuma and one at Sacaton. When examined July 6 one of the rows at Yuma contained two and the other four unmistakable hybrid individuals, and there was considerable diversity among the remaining plants. The row at Sacaton, inspected August 3, contained no obvious hybrids, but the plants were generally infertile, and the row was discarded. In September one of the rows at Yuma was decidedly inferior in the average length, strength, and fineness of the fiber, and no selections were made; only one individual selection was made in the other row at Yuma.

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[a] The plants grown near Los Angeles, both from the acclimatized strain and from imported Mit Afifi seed, were small, and they had few and short limbs; they were conspicuously hairy and had a great deal of red color in the stems and involucres. The bracts were broad, cordate, and deeply toothed. The calyx was distinctly toothed, a character usually peculiar to Upland as distinguished from Egyptian types. The stigmas were exceptionally short.

The seed cotton from the unselected plants in progeny row No. 360 of 1908 was picked and ginned together and the seed was planted at Holtville, in the Imperial Valley, California, in 1909. The soil was very sandy and the seed was planted late, consequently the yield was small. Nevertheless, many of the plants showed a strong tendency to produce a "bottom crop," developing fruiting branches at low nodes on the stem. On a good percentage of the plants the fiber was satisfactory in length and strength. There was considerable diversity in the appearance and vegetative characters of the plants, and a large number of hybrids and otherwise aberrant plants were removed at the end of July.

STRAIN NO. 361.

History.—Individual selection No. 361 of 1907 was a much more productive plant than No. 360, but otherwise greatly resembled it. The seeds were abundantly furnished with lint, the percentage being 32. The fiber had all the characters of a good Mit Afifi and was very fine, strong, and of a good brown color. The length exceeded 1½ inches and was very uniform. In 1908 the progeny row from this plant contained about 6 per cent of hybrids. It was one of the most uniformly fruitful and early-ripening rows in the breeding nursery. The fiber was of typical Mit Afifi character, and was highly satisfactory in fineness, color, and length, although the uniformity of length was somewhat disappointing. The percentage of lint was good. All seed from the unselected plants in this row was picked and ginned together. Mr. John A. Walker reported on the lint from the first picking that it has a "distinctly brown color, even throughout, showing very little white, giving it a greater resemblance to regular Egyptian (brown) than anything ginned to date; has also good 1⅝-inch staple, extra strong and silky. Can be regarded as very satisfactory cotton." The second picking apparently contained a somewhat higher percentage of white fiber, but was otherwise similar. A careful examination of the seed cotton from eleven individual selections in this row showed that in color it was slightly lighter than imported Nubari fiber (footnote *b*, p. 11) in all but two plants, in which is equaled the Nubari. The selections were more uniform in their fiber characters than those from most of the other progeny rows of 1908, the uniformity having been especially marked in respect to color, strength, and fineness.

Five progeny rows of strain No. 361 were grown at Yuma in 1909. In all but one of the rows from one to three hybrid plants were found on July 6; otherwise the plants were very similar in all the rows. Unfortunately these five rows were planted in an unfavorable situation close to a row of cottonwood trees; they were consequently so unproductive and the fiber was so short that no individual selections could be made. The fiber showed more color than was exhibited in the progeny rows of any other strain at Yuma in 1909.

Field test in 1909.—The bulk seed from the unselected plants in progeny row No. 361 of 1908 was planted in 1909 in a field of 3 acres near Yuma. On July 27, the evident hybrids having been rogued out early in the season, the field appeared very uniform. The plants were rather strict in habit and did not develop fruiting branches at the lower nodes,[a] which was doubtless chiefly owing to the rather late planting and to lack of water for irrigation at critical times during the summer. For the same reasons the yield from this field was low and the lint was inferior in length and strength to what might have been expected from the undoubted excellence of the stock. In dry places in the field the strength was especially inferior. There was a marked tendency to uniformity in the characters of the plants and fiber, and the percentage of probable hybrids or otherwise aberrant individuals was small. The bolls held the ripe cotton better than was observed with the Yuma variety. The fiber had an excellent color, intermediate between that of Nubari and Mit Afifi (footnote *b*, p. 11). A considerable number of typical plants in this field, distinguished from the average by greater fertility and better lint, were marked and the seed from these was picked together (bulk selection) for planting a yield-test field in 1910. Ten individual selections were also made by Mr. W. A. Peterson.

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[a] Mr. Argyle McLachlan found that in fifteen representative plants from different parts of this field the average lowest node of the main stem at which a fruiting branch was developed was the fifteenth, hence not lower than in plantings of imported seed of Egyptian varieties. On the other hand, in thirty representative plants from different parts of the 4-acre field of the Yuma variety the first fruiting branch was developed on the average at the tenth node of the main stem. It should be observed, however, that the latter field was planted three weeks earlier than the field of strain 361.

STRAIN NO. 362.

Individual selection No. 362 of 1907 was an exceedingly fruitful plant, with a lint percentage of 29. The fiber was typically Mit Afifi in character, had a good brown color, and was very fine in all but the first picking.[a] In length it exceeded $1\frac{1}{2}$ inches and showed a high degree of uniformity. There was considerable variation in the strength, the later pickings being inferior in this respect. The 1908 progeny row from this plant contained 7 per cent of hybrids. The plants were very similar to those in row 361 (see above). They were very productive and well shaped, with fruiting branches nearly to the base of the stem. The bolls, which opened very early, varied somewhat in size, but were generally medium sized for the Mit Afifi variety. The fiber was of characteristic Mit Afifi type, very fine and lustrous, strong, and well colored. There was a decided lack of uniformity in length of fiber, but the average was about $1\frac{3}{8}$ inches. The seed from the unselected plants in this row was picked and ginned together. The lint was classed by Mr. Walker as "fine" in the first picking and "strictly fine, silky" in the second picking. The length ranged from $1\frac{1}{4}$ to $1\frac{3}{8}$ inches in the first and from $1\frac{3}{8}$ to $1\frac{1}{2}$ inches in the second picking. In both pickings the lint was "wasty." It was "extra strong," but uneven in strength.

Seed cotton from eight individual selections from this row was carefully examined, and proved very similar to that of the selections in row 361. In color the fiber on four of the plants equaled imported Mit Afifi, and on the other four equaled imported Nubari. The length of the fiber on the different plants ranged from $1\frac{1}{4}$ to $1\frac{9}{16}$ inches, but the average was $1\frac{7}{16}$ inches. The fiber was uniformly very fine and generally strong. The lint percentage was good. The seeds varied from smooth to partly covered with fuzz.

The seed of six individual selections was planted in progeny rows at Yuma in 1909. When inspected on July 6 there were from one to three evident hybrids in all but one of the rows, and there was otherwise considerable diversity in foliage and branching habit. In September the plants in all the rows appeared very similar in type of plant and in the character of the bolls and lint. Eight individual selections were made in the six rows.

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[a] It was observed in 1908 that the fiber from the first picking in every lot of cotton grown was coarser and rougher than that from the second and later pickings. This was especially marked in early-ripening types, like No. 362, and was doubtless due to the fact that the bolls opened and exposed the seed cotton to the intense light and dry air long before the first picking was made.

GENERAL CHARACTERISTICS OF STRAINS NOS. 360, 361, AND 362.

The plants of strains Nos. 360, 361, and 362 grown in progeny rows at Yuma in 1909 had an open habit (Pl. I, fig. 1) with a few long, upright, slender limbs nearly equaling the main stem in length; the fruiting branches were long and slender, bearing comparatively few bolls, and generally had a very long basal internode;[a] the foliage rather sparse; the bolls short, rounded, and with a blunt tip (typical Mit Afifi bolls, see Pl. II); the seeds smooth or partly covered with fuzz; and the fiber generally short and strong, fine, and nearly as brown in color as imported Mit Afifi fiber. The percentage of lint was much higher than in the Yuma and Somerton varieties, 25 pounds of seed cotton from the "bulk selections" in the 3-acre field of strain 361 having yielded 31.6 per cent of lint.[b]

These strains constitute a uniform type which shows no marked departure from typical Mit Afifi cotton as grown in Arizona from imported seed, except that the plants are more productive and develop fruiting branches at lower nodes on the stem, open their bolls earlier, and produce lint of better quality. The high degree of uniformity exhibited by the plants in the 3-acre field of strain 361 at Yuma in 1909 indicates a considerable degree of prepotency, since the progeny row which produced this seed in 1908 was situated in the breeding nursery among other rows of very different type, most of which contained numerous mybrids (footnote *b*, p. 12).

IMPORTED SEED OF EGYPTIAN VARIETIES TESTED IN 1909.

As a check on the progress of the acclimatization and selection and in order to compare the amount and kinds of diversity shown by the plants from newly imported seed with that of the acclimatized and selected stocks, seed of the six leading Egyptian varieties (Mit Afifi, Nubari, Jannovitch, Ashmuni, Abbasi, and Sultani) was planted in alternate rows in the Yuma Valley and at Sacaton, Ariz. Larger plantings (one-half acre to 1 acre) of the first four varieties were also made in the Yuma Valley. A plat of imported Mit Afifi was also grown alongside a planting of a select acclimatized stock derived from the same variety at Glendale, near Los Angeles, Cal. (See p. 23.)

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[a] This rather undesirable branching habit does not appear to be inherent in these strains, but seems to be due mainly to the unfavorable situation of these particular rows, which suffered several times during the season from lack of moisture on account of the competition of a neighboring row of trees. In the row which had the most favorable moisture conditions the plants were much more productive, with fruiting branches developed well toward the base and usually bearing five or six bolls each. In this row the bolls were larger than in the others.

[b] Mr. Argyle McLachlan found that 100 delinted seeds of strain 361 weighed 11.75 grams, while the same number of seeds from a sample of imported Mit Afifi weighed only 10 grams. If the seeds weighed no more than the imported (see p. 17), the lint percentage of strain 361 would therefore have been 35.3 instead of 31.6.

The imported varieties differed widely in the amount of diversity shown, this being least in the Mit Afifi and Nubari varieties and greatest in Ashmuni. The Mit Afifi and Nubari varieties showed a high degree of uniformity, indicating that the seed received from Egypt was the result of careful selection in that country. The Mit Afifi, as in all previous plantings of imported seed of that variety, at all places where the comparative plantings were made, showed itself very inferior to the acclimatized and selected stocks in yield, earliness, and quality of the fiber. On the other hand, the Nubari, although by no means equaling the improved strains which have resulted from several years of acclimatization and selection in the Southwest, was decidedly superior in all these respects to any other planting of newly imported seed which has been made in that region. The yield from one-half acre of this variety was 514 pounds of seed cotton, which was equivalent to 290 pounds of lint per acre, the percentage of lint being 28.1.

MISCELLANEOUS EXPERIMENTS IN 1909.

In addition to the plant-breeding experiments and the field tests of acclimatized and imported stocks, a number of other experimental plantings were made near Yuma, Ariz.

Progeny of first-generation hybrids.—Progeny rows of several first-generation Upland-Egyptian hybrids selected in the breeding nursery of 1908 (see footnote *b*, p. 12) were grown. It was observed in 1908 that these first-generation hybrids, when compared with the pure Egyptian plants in the rows in which they occurred, were very superior in fruitfulness, size of bolls, and in the abundance, length, and strength of the fiber. The progenies of the different individuals in 1909 showed considerable difference in the amount of diversity and in the degree in which the characters of the Egyptian or of the Upland parent predominated. None of the plants in any of the rows came near equaling the parent selections in productiveness or in the quality of the fiber. Some of the first-generation hybrid parents had very smooth seeds and others had completely fuzzy seeds. As a rule, the progenies in 1909 showed no uniformity in their inheritance of this character; many fuzzy-seeded offspring were from smooth-seeded parents, and vice versa. An examination of these hybrid progeny rows gave no indication of the likelihood that a superior strain could be developed by this method, and no selections were made in the second generation.

Production of first-generation hybrids.—Under the direction of Mr. O. F. Cook, Egyptian cotton was planted in rows alternating with various Upland varieties in order to test the possibility of securing in this manner a stock of first-generation hybrid seed for commercial planting.[a] The early flowering of most of the Upland varieties, as compared with the Egyptian, indicated that to use this method successfully it might be necessary to select a late-flowering Upland variety for the alternate plantings or else to plant the Upland cotton later than the Egyptian.

Seed selection.—Another experiment, carried on by Mr. Argyle McLachlan, was the planting in separate rows of the different types of seed selected from various imported and acclimatized lots, in order to determine the possible advantage of sorting by hand cotton seed that has become mixed by hybridization, and thus to eliminate aberrant types before planting, thereby gaining greater uniformity in the crop and reducing the opportunity for further crossing.

Different dates of planting.—Row plantings of a single acclimatized stock were made on successive dates throughout the spring in order to compare the effect of early with that of late planting under otherwise uniform conditions upon the fruitfulness and lint qualities of the plants, and to ascertain the best time for putting in the seed. For various reasons this experiment gave no conclusive results, but the matter is an important one and will be made the subject of further experimentation. All the evidence so far obtained points to the advantage of planting Egyptian cotton in the Colorado River region as early in the spring as the weather will permit.

Seed from different pickings.—Seed from the different pickings of several of the acclimatized stocks was planted in rows in order to determine if possible whether the early or the late ripened seed is the most desirable for planting. Only negative results were obtained, none of the three pickings appearing to give generally better results than either of the others, but it is not considered that this problem has been finally solved.

Irrigation.—The conditions in 1909 with regard to the supply of water for irrigation were so unfavorable that no special experiments could be carried out to determine the best method of irrigating Egyptian cotton. There is no question that the yield, uniformity, and quality of the fiber, especially in respect to length and strength, depend in a high degree upon the manner in which the plants are irrigated. This is considered the most important cultural problem remaining to be solved in connection with the production of this crop in the Southwest.

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[a] In a paper entitled "Suppressed and Intensified Characters in Cotton Hybrids," Bulletin 147, Bureau of Plant Industry, United States Department of Agriculture, pp. 15–16, Mr. Cook calls attention to the possible commercial utilization of the superior qualities of first-generation hybrids of Egyptian with Upland cotton.

PRESENT COMMERCIAL STATUS OF EGYPTIAN COTTON IN THE UNITED STATES.

During the latter part of 1909 and the early months of 1910 all types of cotton commanded unusually high prices. The condition of the long-staple cotton market was especially abnormal owing to the operation of a number of independent causes. The advance of the boll weevil in the cotton belt of the South has led to a feeling of uncertainty in the localities which furnish the bulk of our supply of long-staple Upland cotton. Furthermore, the 1909 crop in Egypt was an exceptionally small one, and from all reports the quality of the fiber was unusually poor. Various explanations are offered for the disquieting state of affairs that exists in Egypt. It is widely believed that the construction of the great dam at Assuan, in upper Egypt, and of "high line" canals, with the consequent abundance of irrigating water and increased opportunity for seepage, has resulted in raising the water table throughout the cotton-growing provinces of the Delta to a point that seriously injures the deep-rooted cotton plants.

TABLE II.—*Average prices of Good Fair Egyptian and Middling Upland cottons on the Boston market for each month from January to October, 1909.*[a]

Month.	Average price per pound.		Month.	Average price per pound.	
	Good Fair Egyptian.	Middling Upland.		Good Fair Egyptian.	Middling Upland.
	Cents.	*Cents.*		*Cents.*	*Cents.*
January	17.0	9.9	June	18.5	11.5
February	16.5	9.9	July	19.9	12.9
March	16.0	9.9	August	19.9	12.7
April	16.6	10.5	September	20.2	13.2
May	18.0	11.3	October	22.0	14.4

[a] The average prices of Egyptian and Middling Upland cottons on the Boston and Liverpool markets during the ten years from 1898 to 1907, inclusive, are stated in Bulletin 128, Bureau of Plant Industry, p. 25, tables 4 and 5. Prices during 1908 are discussed in Circular 29, Bureau of Plant Industry, pp. 5 and 6.

TABLE III.—*Average prices of different grades of Egyptian and of Middling Upland cotton on the Boston market for each month from November, 1909, to July, 1910.*[a]

Month and year.	Average price per pound.				
	Egyptian.				Middling Upland.
	Low grades.	Current.	Good grades.	High grades.	
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*
November, 1909	19 -22⅛	20½-23¾	21¾-25⅛	23 -27⅛	15 -15⅛
December, 1909	22½-25⅛	24 -27½	26 -29¼	27¾-31	15 -15⅜
January, 1910	21 -26⅜	25⅞-28⅜	27⅞-30⅜	29¼-32¼	15 -16⅜
February, 1910	22 -27	26 -32	28⅞-33	31¾-35⅛	15 1/16-15 7/16
March, 1910	22¼-28¼	27¼-33¼	32¼-34¼	33½-36⅞	15 7/16-15 9/16
April, 1910	20½-27⅞	23¾-32⅞	28¼-33⅛	31¼-36⅞	15 1/16-15 5/16
May, 1910	19¾-22¾	23¼-26¼	26¾-30⅜	29¾-33	15 5/16-15 13/16
June, 1910	17¾-22¾	19¾-26¼	21¾-30⅜	22¾-33	14⅞ -15¼
July, 1910	17⅛-20¼	19¼-21¾	20¾-22¾	21¾-24¼	15¼ -16

[a] The prices for each month are the minimum and the maximum of the weekly prices for each grade as quoted in the Commercial Bulletin, published at Boston.

It would be unwise to rely upon a maintenance of the recent very high level of prices. During the ten years from 1898 to 1907, inclusive, the average price on the Boston market of all grades of Egyptian cotton imported was 15.3 cents, as compared with 9.5 cents for Middling Upland. During 1908 the average price of Egyptian cotton on the same market was 18.07 cents, as compared with 11.11 cents for Middling Upland. It should be noted, however, that these prices cover the total quantity of Egyptian cotton imported, much of which belongs to very inferior grades. Fiber of a quality such as experiments have demonstrated can be produced in the Southwest would be expected to command a premium of several cents over the average.

The total imports of Egyptian cotton into the United States during the calendar year 1909 amounted to 72,617,893 pounds, valued at $12,101,000, as compared with 61,511,723 pounds, valued at $11,560,009, in 1908.

CONCLUSION.

In summing up the most important results of the breeding work with Egyptian cotton in 1909, it is noted that the diversity caused largely by crossing with other types of cotton, which in 1908 seemed to seriously threaten the future of the acclimatized stock, has to a great extent disappeared. This is doubtless partly due to the planting of carefully selected types. The most promising of these is apparently a mutation and shows a strong tendency to be prepotent; in other words, to maintain its uniformity even in the presence of opportunity for crossing with other stocks. The application of methods of eliminating hybrids and aberrant individuals before the plants begin to open their flowers which Mr. Cook has worked out as a result of his diversity studies has also greatly contributed to this result.

The breeding work of the past seven years has developed several superior strains and two very distinct varieties which are now ready for testing on a field scale. The two varieties—the Yuma and the Somerton—developed from an imported stock of the Mit Afifi variety, represent a wide departure from the characteristic parent type. In their large, pointed bolls and lighter colored fiber they more nearly approach other Egyptian varieties, which are also believed to be derived from Mit Afifi and probably originated in the same manner as "sports" or "mutations." One of the new strains represents typical Mit Afifi in the shape of its bolls and in the deeper color and other characteristics of its fiber, but is notably superior to the average of that variety, at least as grown in the United States from imported seed. This strain, which was grown last year on a field scale, likewise exhibited a high degree of uniformity.

Experiments in 1909 with these well-marked new varieties indicate that transfer to a new locality having somewhat different climatic and soil conditions does not induce diversity to anything like the extent that results when newly imported seed or mixed seed of different acclimatized stocks is planted in new places. Thus the very distinct Yuma variety, which was first distinguished and very likely originated at Yuma, Ariz., maintained its superior uniformity, productiveness, and distinctive type of plants and of fiber when planted under the decidedly different conditions existing at Sacaton, Ariz., and in the Imperial Valley, California. The equally distinct Somerton variety, which also probably originated near Yuma, maintained its superiority to newly imported seed at Sacaton and at Los Angeles, Cal., although in the latter locality, which represents an extreme departure from the climatic conditions existing in the Yuma Valley, the general appearance of the plants was very different. It is therefore apparent that the difficulties of "local adjustment" or adaptation of an acclimatized strain to the varying climatic and soil conditions of different localities in the region in which the acclimatization has taken place are not likely to interfere seriously with the extensive utilization of selected types possessing a high degree of prepotency such as are described in this paper.

SUMMARY.

Several distinct and promising varieties and strains which have resulted from the acclimatization and breeding experiments with Egyptian cotton in the southwestern United States were tested on a field scale in the Colorado River region in 1909 and gave very favorable results in regard to the quality and uniformity of the fiber produced.

The results of the season's work showed that by planting carefully selected types and by "roguing out" the markedly aberrant individuals early in the summer the degree of uniformity can be attained which is demanded by the market for this class of cotton.

Diversity can be still further controlled and the fruitfulness of the plants maintained by avoiding extremely light and extremely heavy types of soil and by managing irrigation so that the plants are not exposed to alternations of severe drought and excessive moisture.

Samples of the fiber produced in 1909 were submitted to a number of spinners and other experts, who were unanimous in pronouncing them equal in all respects to imported Egyptian cotton of corresponding grades.

Two of the best types (the Yuma and Somerton varieties) are so distinct from the Mit Afifi variety from which they have been derived as to warrant the belief that they are mutations and have originated in the same manner as Abbasi, Jannovitch, and other superior types which have been developed in Egypt from the Mit Afifi variety.

A third type (strains 360, 361, and 362) resembles Mit Afifi in all characters of the plants, bolls, and fiber, but the plants are much more productive and produce fiber of better quality than those grown in the same region from imported seed. This type is to be regarded as an acclimatized and improved Mit Afifi rather than a new variety.

The Yuma variety was tested in a field of 4 acres near Yuma, Ariz., in 1909, and showed a very satisfactory degree of uniformity in the productiveness and habit of the plants and in the quality of the fiber. It is characterized by a strong tendency to develop a stout main stem greatly surpassing the limbs, and possesses long fruiting branches, long taper-pointed bolls, and strong, silky, cream-colored fiber, averaging about $1\frac{3}{8}$ inches in length.

The Somerton variety resembles the preceding in the length of its bolls and in most of its fiber characters, but the bolls are more sharply pointed, the seeds generally smoother, the percentage of lint smaller, and the plants more bushy, with a greater development of large vegetative branches.

The group of strains Nos. 360, 361, and 362 constitutes a uniform type that is very different from the Yuma and Somerton varieties. The plants are of open habit, with several large limbs nearly equaling the main stem; short, plump, abruptly pointed bolls; and strong fiber of medium length (averaging $1\frac{1}{4}$ to $1\frac{3}{8}$ inches). In color the fiber is almost as brown as that of imported Mit Afifi.

Other more or less distinct types have been developed, but are either less satisfactory or have not yet been sufficiently tested.

Imported seed of the principal Egyptian varieties was planted in 1909 in Arizona in the vicinity of Yuma and at Sacaton. The varieties differed greatly in the amount of individual diversity manifested. None of them equaled the acclimatized stocks in fruitfulness or in quality of the lint.

Progenies of a number of first-generation Egyptian-Upland hybrids were grown near Yuma. The second-generation plants showed excessive diversity of type, but none of them could compare with the first-generation parents in yield or in excellence of the fiber.

The imports of cotton from Egypt into the United States during the calendar year 1909 amounted to 72,617,893 pounds, valued at $12,101,000, as compared with 61,511,723 pounds, valued at $11,560,009, in 1908.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Fig. 1.—A fertile plant of acclimatized Egyptian cotton of the type characteristic of strains Nos. 360, 361, and 362, with several large ascending vegetative branches nearly as long as the main stem and bearing a considerable percentage of the bolls. Grown near Yuma, Ariz., in 1908. Fig. 2.—A plant of the Yuma variety of acclimatized Egyptian cotton with a tall, stout main stem bearing most of the bolls and with the vegetative branches much reduced. Grown near Yuma, Ariz., in 1908.

Plate II. Typical bolls and bracts (natural size) of Mit Afifi Egyptian cotton grown from imported seed near Yuma, Ariz., in 1908.

Plate III. Typical bolls and bracts (natural size) of the Yuma variety of acclimatized Egyptian cotton grown near Yuma, Ariz., in 1909. Note the larger and more pointed bolls as compared with typical Mit Afifi (Pl. II).

Plate IV. Typical bolls and bracts (natural size) of the Somerton variety of acclimatized Egyptian cotton grown near Yuma, Ariz., in 1909. The bolls are more sharply pointed than in the Yuma variety (Pl. III).

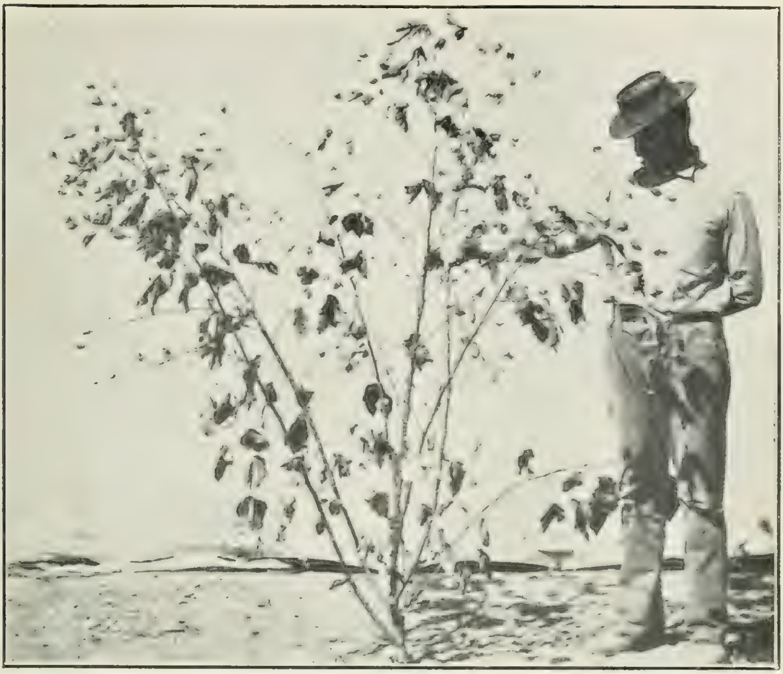


FIG. 1.—A FERTILE PLANT OF ACCLIMATIZED EGYPTIAN COTTON.

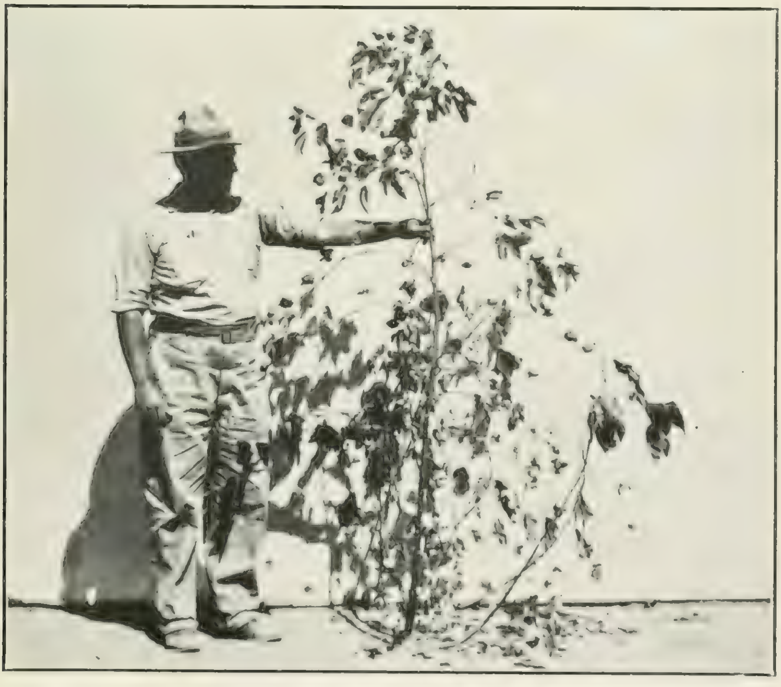
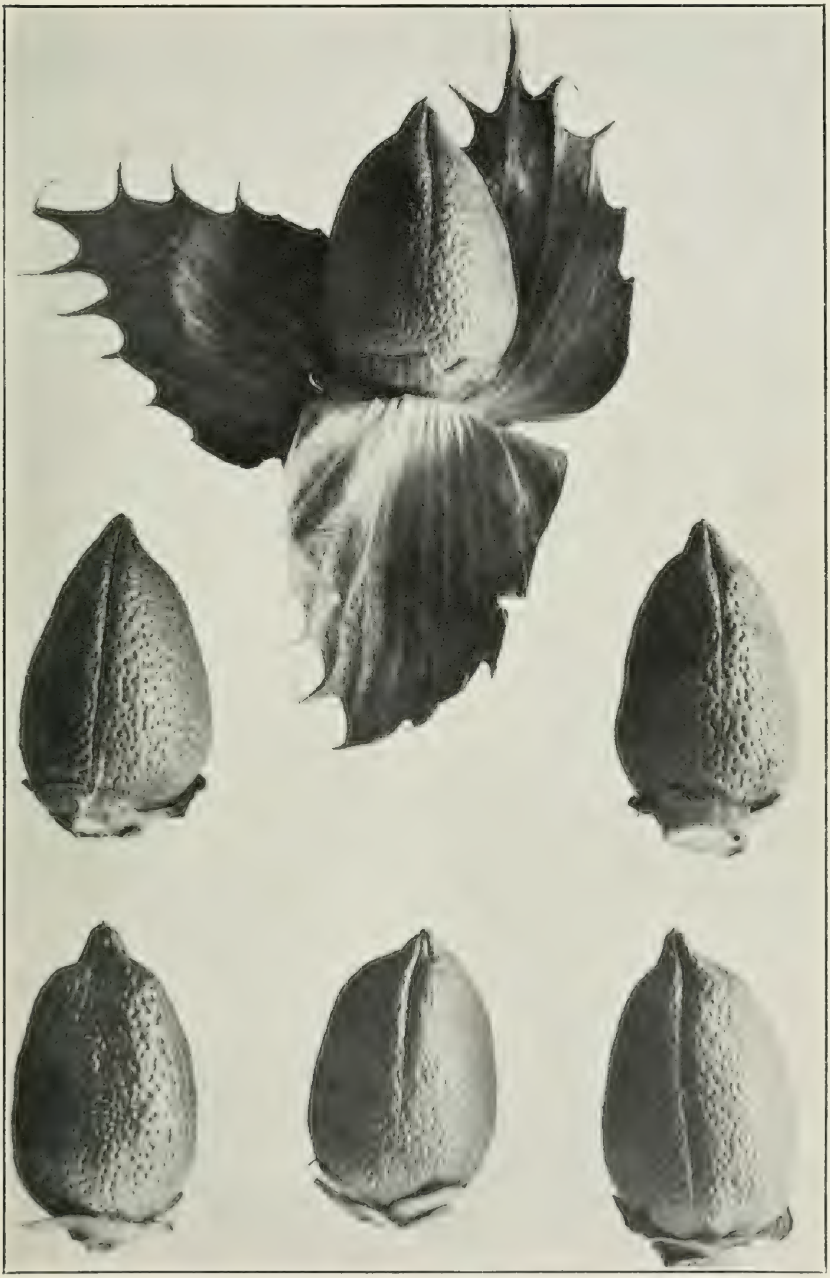
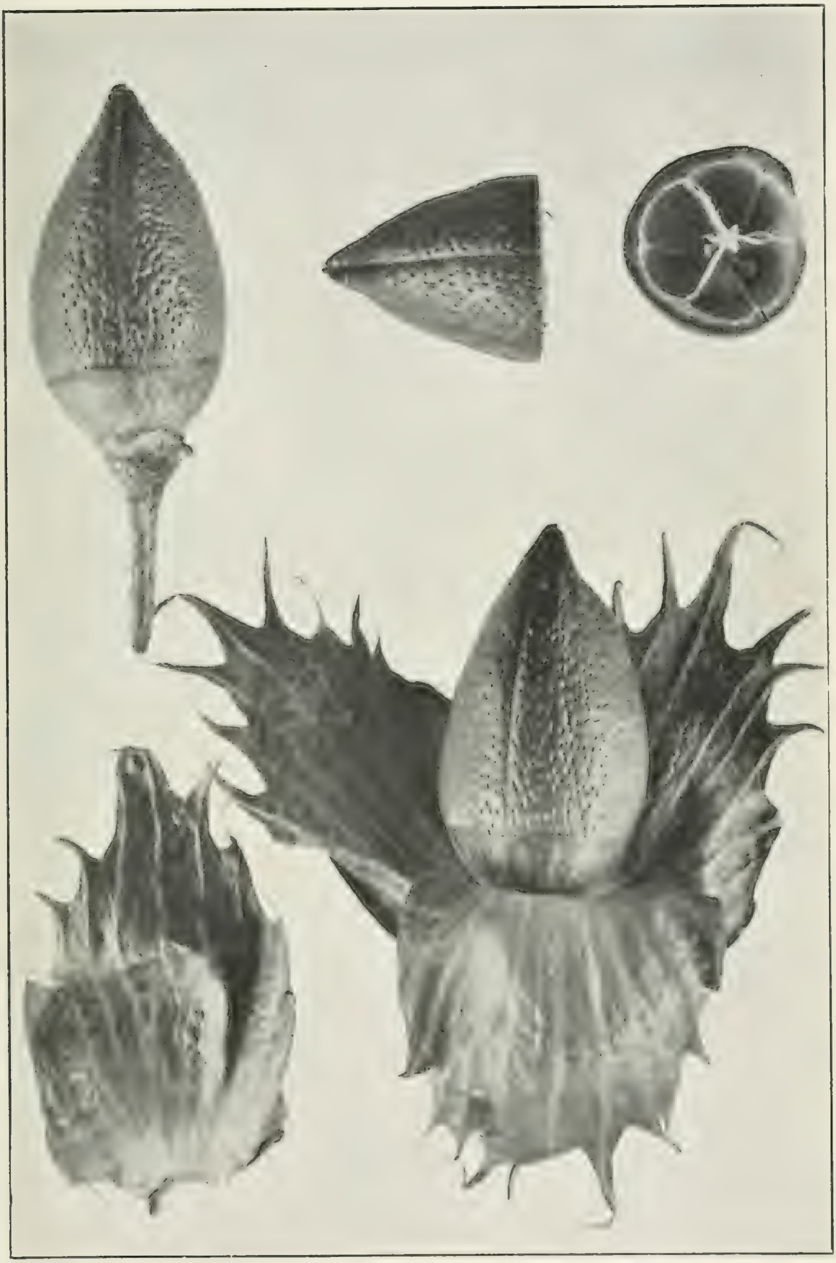


FIG. 2.—A PLANT OF THE YUMA VARIETY OF ACCLIMATIZED EGYPTIAN COTTON.



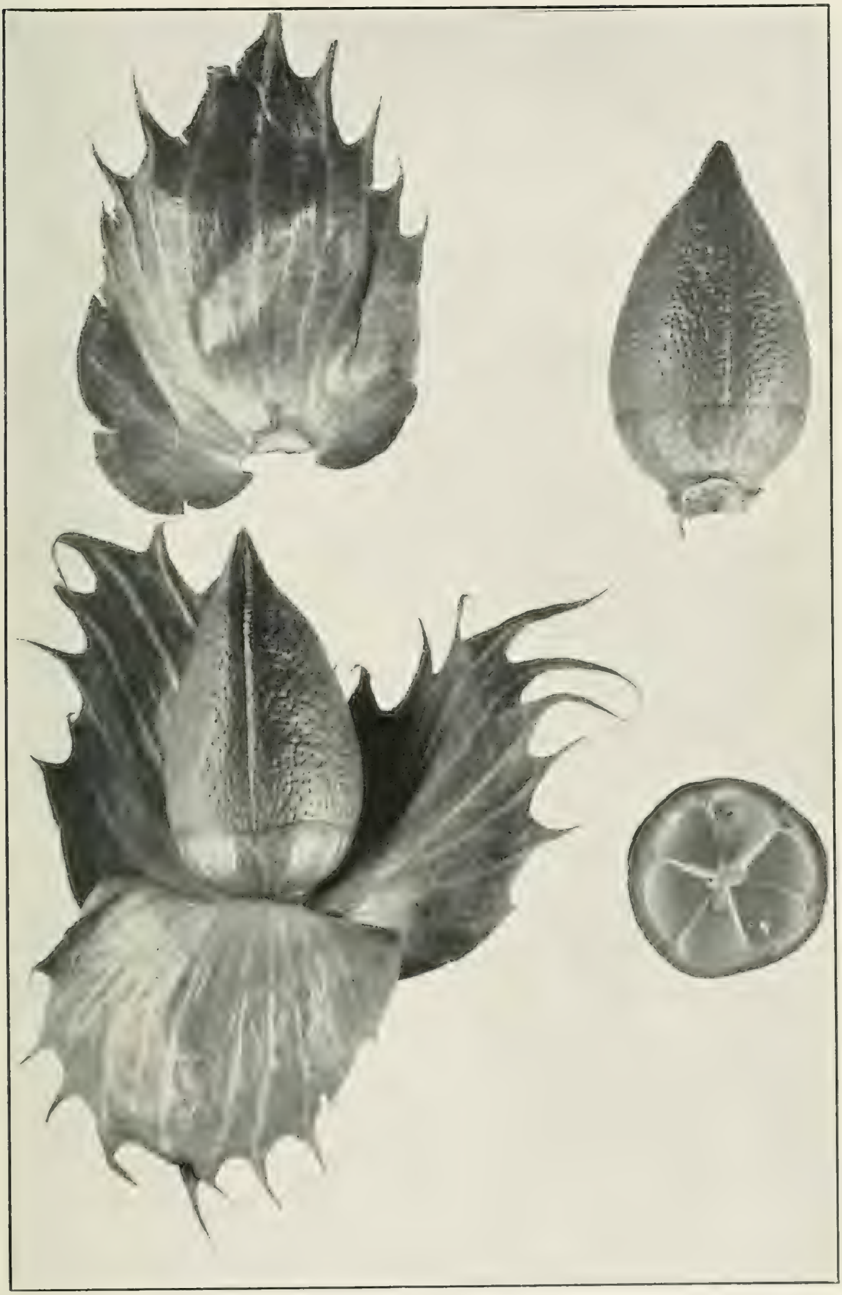
TYPICAL BOLLS AND BRACTS OF MIT AFIFI EGYPTIAN COTTON GROWN FROM IMPORTED SEED.

(Natural size.)



TYPICAL BOLLS AND BRACTS OF THE YUMA VARIETY OF ACCLIMATIZED EGYPTIAN COTTON.

(Natural size.)



TYPICAL BOLLS AND BRACTS OF THE SOMERTON VARIETY OF ACCLIMATIZED EGYPTIAN COTTON.

(Natural size.)

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